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HENLEY'S ENCYCLOPÆDIA

OF

PRACTICAL ENGINEERING

AND ALLIED TRADES

A PRACTICAL AND INDISPENSABLE WORK OF REFERENCE FOR THE MECHANICAL ENGINEER, DESIGNER, DRAFTSMAN, SHOP SUPERINTENDENT, FOREMAN AND MACHINIST.

Encyclopædic in scope, thorough and practical in its treatment of technical subjects, simple and clear in its descriptive matter, and without unnecessary technicalities or formulæ. The Articles are as brief as may be and yet give a reasonably clear and explicit statement of the subject, and are written by men who have had ample practical experience in the matters of which they write.

EDITED BY

JOSEPH G. HORNER, A.M.I.MECH.E.

AUTHOR OF "PRACTICAL METAL TURNING," "MODERN MILLING MACHINES," "PATTERN MAKING," "TOOLS FOR MACHINISTS, AND WOODWORKERS," ETC., ETC.

ASSISTED BY A CORPS OF PRACTICAL MEN, EACH A SPECIALIST IN THE SUBJECT OF WHICH HE WRITES.

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The Encyclopædia

OF

Practical Engineering and Allied Trades.

Boiler Plate.—*See* **Boilers—Materials for.**

Boiler Plate Gauge.—*See* **Caliper Gauge.**

Boiler Scale.—This consists chiefly of sulphate of lime, and the carbonates of lime and magnesia. A thin coating of scale soon forms in all boilers, and is not injurious, but when it exceeds from $\frac{1}{32}$nd to $\frac{1}{16}$th in thickness means should be taken to prevent its deposition, or to remove it by the scaling hammer. It is generally possible by analysing a scale to learn to what constituents its presence is due, and to devise suitable measures for its prevention. The following are analyses of typical scales:—

CARBONATE SCALE (Lewes).

	Percentages.
Carbonate of lime	75·851
Sulphate of lime	3·681
Magnesium hydrate	2·56
Sodium chloride	0·45
Silica	7·66
Oxides of iron and alumina	2·96
Organic matter	3·64
Moisture	3·20
	100·000

SULPHATE SCALE (Sylvester).

	Percentages.
Carbonate of lime	2·490
Sulphate of lime	74·280
Magnesium hydrate	18·000
Alumina, and hydrate of iron	1·276
Silica	1·830
Organic	2·124
	100·000

(A very hard scale, which had to be chipped from the plates.)

SALINE SCALE (Lewes).

	Percentages.
Sulphate of lime	46·06
Chloride of sodium	38·66
Magnesium hydrate	4·16
Silica	1·09
Alumina, and oxide of iron	0·65
Water	9·38
	100·00

SCALE PRODUCED BY DIFFERENT WATERS (Lewes).

	River.	Brackish.	Sea.
Calcic carbonate	75·85	43·65	0·97
Calcic sulphate	3·68	34·78	85·53
Magnesic hydrate	2·56	4·34	3·39
Sodic chloride	0·45	0·56	2·79
Silica	7·66	7·52	1·10
Oxides of iron and alumina	2·96	3·44	0·32
Organic matter	3·64	1·55	Trace
Moisture	3·20	4·16	5·90
	100·00	100·00	100·00

Boiler Scaling.—Chipping hard scale from the interior of a boiler with a chisel-like tool, termed a scaling hammer.

Boiler Seatings.—Refers to the brick-work ledges on which horizontal boilers rest over their flues. Also to the intermediate attachments by which various valves and manholes are riveted to boiler shells. These will be found noted under descriptions of different kinds of boilers.

Boiler Setting.—The setting of a boiler denotes the arrangements of brick-work flues over which the shell is laid.

Boiler Shell.—This is the outer cylindrical

part of a steam boiler as distinguished from the furnaces and flues.

Boiler Shell Drilling Machine. — The difference between the earlier and present-day machines lies chiefly in dividing arrangements, and in the multiplication, and position of spindles, the horizontal being embodied frequently, whereas all the earlier machines had vertical spindles only.

The beginning of the displacement of punching by drilling for boiler plates was due to the late Mr Daniel Adamson, following a terrible boiler explosion, the scene of which he visited in Manchester. The first boilers having shells drilled in position were made in 1862, of steel, and worked at 50 lb. pressure. With the introduction of steel, drilling became an absolute necessity, alternatively with ample reamering following punching.

The early drilling machines were built to drill one or more holes, using vertical spindles on flat plates singly, which plates had to be bent subsequently. The result was that after the plates were bent, the holes would not match, and drifting was resorted to, just as when the punch was used. Then followed the mounting of the rings on rollers, the shell lying with its axis in a horizontal direction, and bringing radial drilling machines over the seams. These commanded both longitudinal and circular seams, but the spacing had to be done by hand to centre pops, or circles of rivet holes previously marked from templet, or by hand. A good many of these machines were made, and are still in use. Soon the multiple spindle design was introduced, but in a rather crude fashion. The shells were suspended vertically, and the seams drilled by means of two or more drills operating round the circumferential seams, and driven simultaneously. But the drills had to be set and started, and withdrawn by hand, and so the economy sometimes was often less than that of a single spindle machine. Several circular settings were necessary before the shell could be completed, and for every hole in the longitudinal seams the shell had to be lifted and reset. Following this came the employment of two drilling heads on opposite sides of the shell, with spindles also on the inside for countersinking, or removing the arris. Automatic feed and withdrawal motions were next included, but the pitching was still done by hand. Afterwards the drills were connected, to advance and recede simultaneously, and the pitching was effected by change wheels connected to worm gear, actuating a central table on which the shell was carried and rotated. The objection to this was that the standards carrying the drill heads were themselves advanced and receded, which detracted from the rigidity essential to the proper working of these machines. Then came the fixed standards, with adjustments for centres of drills, and quick withdrawal, and multiple spindles capable of being set to varying angles, and with simultaneous or independent adjustments, with finer feeds, and higher speeds, counterbalanced sliding heads, and minor details.

Present-day machines have become so highly specialised that no single machine can claim the title of boiler shell drill. With the circular row of horizontal spindles there is frequently included a row of vertical spindles carried on another column for longitudinal seams. But many machines have one standard only. Those for dealing with the shells of marine boilers are made to operate while the shell lies horizontally, contrary to the practice in the Lancashire and land types. Hence the first named has several standards placed at an angle, each carrying a single saddle, and spindle.

In one type of boiler shell drill the circular chuck is mounted on a carriage made to travel along a bed, to and from two standards which carry the drilling heads. In this way the radii for boilers of different diameters are set. The drill standards are mounted on a bed having its longitudinal axis at right angles with that of the chuck bed, and along which the standards are adjustable. They are also adjustable radially on their saddles by means of worm gear, to direct the drills to the centre of the shell at all positions of the standards and chuck. The drills, one or more in number on each standard, have independent movements, and quick withdrawals, while their carriages are adjustable for height. An example of a machine is shown in Fig. 1, Plate I.

Boiler Shop.—This department varies much in its dimensions and equipment, the differences

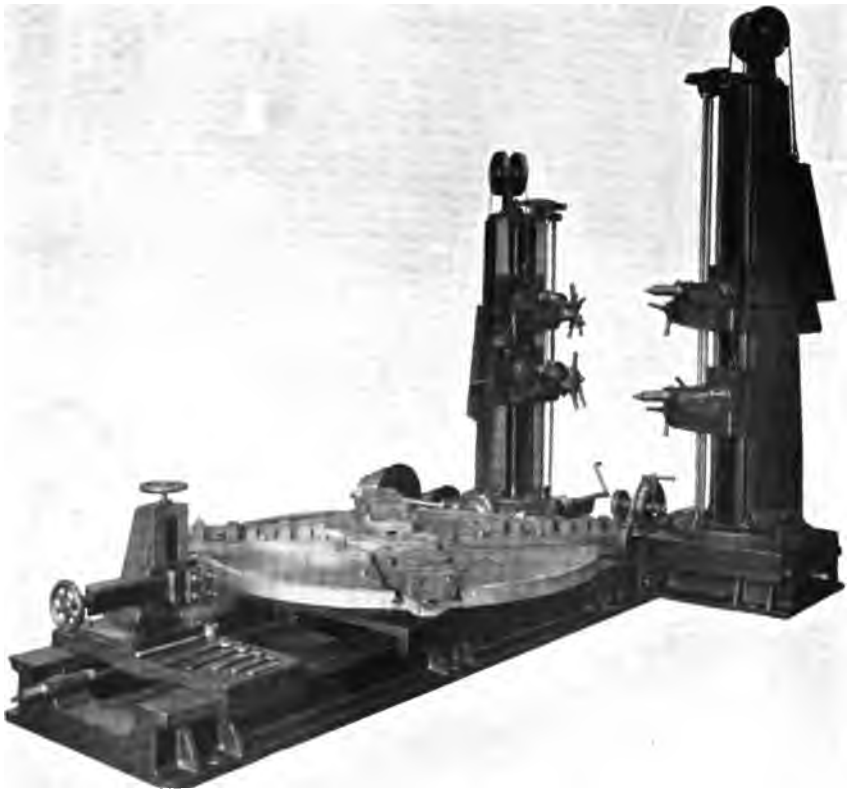


Fig. 1.—Boiler Shell Drilling and Turning Machine. (Rushworth & Co.)

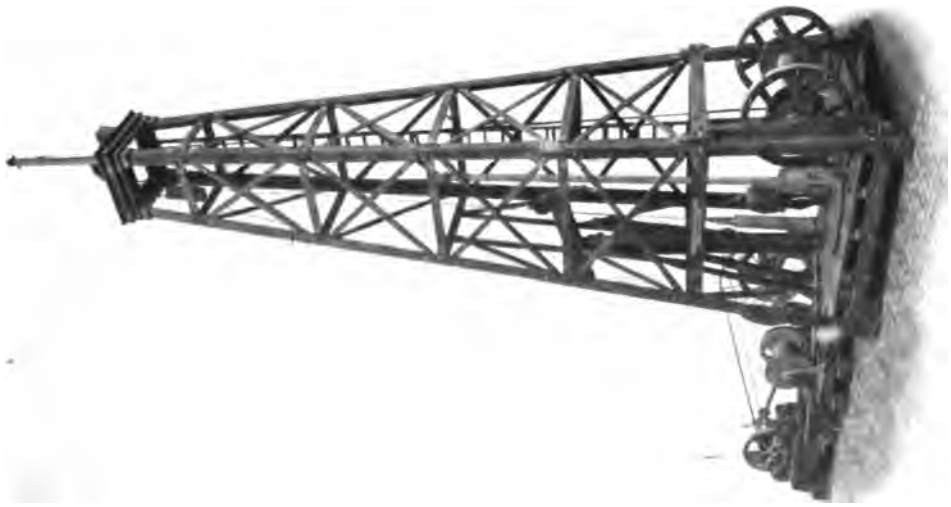


Fig. 22.—Round Rope Boring Plant. (Mather & Platt, Ltd.)

To face page 4.

being due partly to the class of work done, but mainly in the extent to which machines and appliances are used to supplement or displace hand work.

There are few shops in which all classes of boilers are made. Generally marine boiler work stands alone, and locomotive also, in the locomotive shops. But generally boilers of the latter type for portable engines and fixed undertype engines are made in the agricultural shops, along with vertical and horizontal boilers of Cornish and Lancashire types. The last three are also commonly made in the regular boiler shops, but the locomotive and marine are seldom included, though the smaller marine boilers are sometimes undertaken.

Water-tube boilers stand alone, since they include more of the work of the machine shop and the plater than of the regular boiler shops. Another branch of boiler work is that done for the trade, comprising flanging chiefly, large numbers of flanged plates being purchased by firms who have not the necessary plant for their production, but who work them into the boilers which they construct.

The work of the boiler shop requires machines having capacities and powers which vary widely with the size and weight of the work done. There is a great difference, for example, between the machinery required for making vertical boilers, and the boilers for battleships and liners. There are also differences, not only in the capacities, but in the types employed, due to the difference in handling, heating, and operating on relatively small and massive plates. The shop managements also will vary for similar reasons.

A boiler shop generally has one bay, but in the larger ones there may be several bays. The best general arrangement is as follows:—

Either a central area down the shop, or a bay must be kept as clear as possible for work in transit, and in progress. Boilers in course of erection are built to one side, in order not to encroach on the central area. All machines should be set at the sides also. The best position for these when there are bays adjacent is close to the columns which divide the bays, provided the columns do not interfere with the handling of material. Another good alternative arrangement is to place the heavier machines at one end of the shop so that the heavier mechanical operations can all be performed in one locality. The power house may be adjacent thereto. In a modern boiler shop this includes steam, hydraulic, pneumatic, and electrical plant. Steam is used for the engines in the power house and for driving machine tools. Pressure water for the presses, and often for wall jib cranes, and riveting. Compressed air for riveting, chipping, and caulking, and electricity for cranes, for operating machine tools, and for lighting. The overhead electric travelling crane is necessary for handling the plates for boilers and carrying them about the shop, while the jib cranes serve certain areas where the large machines are located and where the boilers are being erected. The forges for the **Angle Iron Smiths** are located preferably down one side.

The principal groups of machines used in the boiler shop are those for cutting off, shearing and punching, planing, flanging, bending, drilling, and riveting. The varieties in each great type are numerous and will be found described under their appropriate headings, so that a brief outline only of the nature of, and necessity for the operations involved need be given here.

The cutting off of bars is frequently done at the anvil with the hot or cold sett, but that involves subsequent planing, or chipping. The **Cold Saw** severs bars to neat lengths, leaving the ends neatly finished. Plates are shorn to approximate dimensions at the steel mills, leaving the edges to be trimmed in the boiler shop in **Shearing Machines**, or finished in **Plate Edge Planing Machines. Angle Iron Shears** are employed for cutting that particular section to length, or the cold iron saws can be employed for any sections used in the shop. Holes when punched are generally done in combined Punching and Shearing Machines. Plates are bent by means of **Bending Blocks**, or in an **Angle Bending Machine**. Other sections are generally done by the aid of bending blocks. Flanging is done by hand by the methods described under **Angle Iron Work**, or in **Flanging Machines** of various types, by fitting special blocks in the machines described under their heads.

Drilling is performed in various machines described under **Boiler Flue Flange** and **Boiler**

Shell Drilling Machines, and under **Radial Drilling Machines**. Riveting is done by the aid of hydraulic and pneumatic riveters. Caulking is performed by hand, or in the best practice by portable pneumatic caulkers. Template making is a branch of boiler work, and boiler testing is a sub-department of the shop.

Boiler Smithy.—A department of the boiler shop distinct from the plating, punching, drilling, and riveting. The work done is that at the forge only, involving bending, flanging, welding, and allied operations. The workman is termed an **Angle Iron Smith.**

Boilers—Materials for.—Special qualities of iron and steel for the plates of steam boilers have always been insisted on, since boiler inspection became recognised as necessary to safety.

Iron plates may now be dismissed summarily because they are but little used. The usual test was that iron plates of B B quality suitable for furnace flues should show a tensile strength of 21 tons with the grain, and 18 tons across the grain, with an elongation of not less than 10 per cent. in 8 inches. This elongation varies with the direction, being 14 or more with, and 8 to 10 across the grain. For shell plates, B quality of about the same strength, but lower ductility was used. Yorkshire iron was, and is still often used for the furnace flues of the best boilers. It was even put into the shells of some boilers, but its high price was generally prohibitive.

At the present time little iron is put into boilers, but steel mostly.

Lloyds' rules for steel shell plates are, an ultimate tensile strength of not less than 27 tons, and not more than 32 tons per square inch of section. If the plates are to be flanged or welded, the ultimate strength must not exceed 30 tons. The reason for this is that high tensile strength is incompatible with high ductility. The ultimate tensile strength of all other plates and of screw stays is to be not less than 26, and not more than 30 tons per square inch of section. In all cases the elongation is to be not less than 20 per cent. in a length of 8 inches. Cold bending tests are also to be made on strips sheared either lengthwise, or crosswise of the plate. These must stand bending double round a curve of which the diameter is not more than three times the thickness, and they are to be bent without annealing. Samples are also to be heated to a low cherry red and cooled in water of 82° Fahr., and then bent to a curve the inner radius of which is equal to one and a half times the thickness of the plate.

Tests of other inspecting bodies do not vary much from the above. They are summarised below.

British Admiralty.—(*a*) Tensile test not less than 26 tons, and not exceeding 30 tons for plates not exposed to flame, with a limit of elasticity of not less than 14 tons per square inch of section. (*b*) Not exceeding 27 tons for furnace and other plates exposed to flame, and with an elongation taken on a length of 8 inches of not less than 22½ per cent. for plates exposed to flame, and not less than 20 per cent. for other plates. The hot bending test is the same as Lloyds.

Board of Trade.—Tensile test 26 to 30 tons for plates exposed to flame, and with 20 per cent. elongation in 10 inches. Shell plates and plates not exposed to flame, 27 to 32 tons, with 20 per cent. elongation in 10 inches. Bending test the same as Lloyds. Bureau Veritas tests are substantially similar to those of the Board of Trade.

Ordinary specifications for steel without extras imply a range of 4 tons in tensile tests; as, 26 to 30 tons with a minimum extension of 20 per cent. in 8 inches. If narrower limits are demanded, they are subject to special quotations. Ordinary bending tests, cold, and temper are not charged extra. More severe conditions involve extra charges. A rolling margin of 5 per cent. is usually required. But very wide sheets cannot be guaranteed within this limit owing to the springing of the rolls.

The boiler plates of the present time differ from those of a few years since in being larger, with a diminution in extras for those above limiting sizes, and sketch plates. The standard plate used for the shell of a Lancashire boiler is now 22 ft. long by 4 ft. 6 in. or 5 ft. wide. The result is that the number of longitudinal seams is lessened, and that smaller plates are often cut from larger ones. At present boiler plates range from £7 to £9 a ton, according to quality.

MAXIMUM DIMENSIONS OF STEEL PLATES AND SHEETS. (THE PARKGATE IRON AND STEEL CO., LTD.)

Thickness.	Rectangular Plates. Maximum. Length.		Width.		Area.	Circular Plates. Maximum Diameter.	
in.	ft.	in.	ft.	in.	ft.	ft.	in.
1/16	8	0	4	0	32	4	0
3/32	8	0	4	0	32	4	0
1/8	12	0	5	0	50	5	0
5/32	20	0	5	0	72	6	0
1/4	40	0	6	0	100	6	6
5/16	40	0	6	6	100	7	6
7/16	40	0	7	0	130	8	0
1/2	45	0	9	0	160	9	0
9/16	50	0	10	0	200	10	6
5/8	50	0	11	0	250	11	6
7/8	50	0	11	6	250	11	9
1	60	0	11	6	250	11	9
1 1/8	60	0	11	6	250	11	9
1 1/4	50	0	11	6	250	11	9
1 1/2	50	0	11	6	200	11	9
1 3/4	50	0	11	6	180	11	9

Plates over 1¾ in. and up to 6 in. thick are cut to dimensions in a planing machine, and are subject to special quotations.

The area divided by the length gives the width of a plate that can be rolled in any given thickness, and the area divided by the width gives the length.

See also **Copper, Extras, Furnace Flues, Fire Boxes, Yorkshire Iron.**

Boilers, Steam. — The leading types of steam boilers will be found illustrated under their different headings. The following is a concise classification only.

Land, marine, and locomotive was the old division, which is not now sufficiently discriminative, since some land, and some marine types are employed in both kinds of service. Another division which for many years covered two extensive groups was that of externally, and internally fired. The former has lessened, and only survives until existing examples are worn out. It includes the wagon boiler, and balloon, or hay-stack boiler, the Rastrick boiler, and the egg-ended or hemispherical-ended boilers, set in brick-work enclosing smoke flues. The internally fired group includes all other boilers, excepting the water-tube type, which is a group by itself.

The simplest types of internally fired boilers are the Cornish, and the Vertical, the first named comprising a cylindrical vessel set horizontally, the second, one set vertically, the furnace being placed within, and the products of combustion passing away through tubes, flues, or uptake. The Lancashire and Galloway boilers are modified forms derived from the Cornish, and more efficient. The verticals are a numerous group, the members of which vary from one another chiefly in tube arrangements.

Another division is that between boilers that are set in brick-work—the old land boilers, and those which are not. The Cornish and its derived forms are laid on brick-work flues in order to increase their efficiency by the prolongation of the period of contact of the products of combustion with their sides, in other words by increasing their heating surfaces. The length of these boilers is increased, in order to prolong the period of contact, to about four times their diameter. The Scotch or cylindrical marine boiler is a very much modified horizontal type, in which reduced length receives compensation in a large combustion chamber into which hundreds of fire tubes enter, and which return from the chamber end through the shell. The multitubular fire tube device is embodied in the locomotive type of boiler, and thence has been extended to boilers for torpedo boats, to those for agricultural engines of fixed and portable types, and in numerous cases to Cornish and Vertical boilers.

The water-tube boilers have few points in common with the foregoing. Hundreds of tubes contain the water around which the flame from the furnace below plays, while the steam is received in a drum overhead, into which directly, or through headers the tubes are connected above as they are to the water chambers below. These boilers are set in brick-work, or in casings of sheet steel, and are fired by hand, or with mechanical stokers similarly to ordinary horizontal boilers. The so-called flash boiler is a special water-tube type.

Boiler Testing.—Boilers are tested to ascertain their evaporative duty for the purpose of proving their efficiency to the satisfaction of the purchaser in some instances, or to show the value of some principle of design. Tests may be commercial or scientific. A so-called scientific boiler test is one in which, by the aid of an extensive staff of assistants and a plethora of instruments, every item is checked and a correct heat balance is attempted. Such tests are rarely possible on ordinary plant, and even where specially carried out, the extremely fine calculations are usually found to be entirely vitiated by some one, or two data that have been arrived at by guesswork.

A commercial test is one carried out on less pretentious lines by more practical men, and the results obtained are sufficiently accurate for the purpose in view, and depart very little from exact accuracy if carried out well. The real object, technically stated, of a boiler test, is to learn about the transfer of heat from fuel to what is ultimately steam, with a view to showing first how much of the heat capacity of the coal or other fuel is ultimately transferred to the steam; and secondly, what is the quality of the steam in respect of moisture.

It is probable that no "scientific" test that has ever been made on a boiler giving saturated steam is worth the paper it is written upon as a scientific test, for the reason that though there are instruments that will give the quality of the steam passed through them, there is no instrument or known method which will enable a sample of steam to be drawn from a steam pipe of which it is possible to say such sample is a truly representative sample of the steam that is flowing in the pipe.

When steam is superheated, however, it is dry, and the extent of such dryness can be known by the aid of a thermometer, which will tell just how much the steam is hotter than the boiler. It is possible by electrical means, or by the aid of an independent supply of superheated steam, or by the help of a gas-heated dryer, so to dry the steam output of a boiler that its wetness can be calculated with some approximation to accuracy if it ever became necessary to secure such accuracy of statement.

A boiler test must be carefully arranged, and very usually the results obtained are better than everyday results, because firemen and others unconsciously put forth efforts in excess of the ordinary in such matters as careful firing.

If a good record is sought, certain precautions are taken. Other tests may be taken without such precaution. Inventors are particularly prone to make tests on boilers as they first find them, and then having put everything in order, to put on some patent appliance and show much better test results, which are attributed to the patent appliance entirely. There is a class of engineers who lay themselves out to make this manner of test, knowing all the time its worthless and misleading nature, and yet not pointing out those matters which, however patent to the expert engineer, are not apparent to the lay public which is to be plundered. We will suppose a test has been made on a boiler plant to show the effect of bad conditions, and the good conditions test is now to be made. It will be necessary to take certain precautions. Should the blow-out tap be in poor order it may be made good, or if water leaks past it, the blow-out pipe may have a blank flange bolted on to stop loss. The safety-valves must be tight, and where the boiler will safely bear it, an additional few pounds of loading may be permitted to prevent loss by blowing. Water gauges must be in good order, and generally every care must be taken to stop all losses of water, for many of the high record tests of steam boilers have been due to the blow-out tap leaking. When the feed water passes through an economiser, the same precautions are necessary with the blow-out taps and safety-valves of this apparatus as with the boiler.

In order to measure the amount of water put into the boiler, several methods may be employed according to the conditions and circumstances of the plant. Often there is a large tank that will supply all the water required during the continuance of the test. In that case the tank, which will usually be rectangular, must be carefully measured for area, and a suitable allowance made for flanges and internal ribs. The water consumed is best measured by a point and hook gauge, the point of the hook coming up to the surface from below, and the whole sliding on a rod. When the tank has a full length glass gauge, this should be supplied

with a measured rod so that the depth of water can be read at regular intervals. The feed pump must be regulated so that the water level in the boiler tested shall be maintained at a given mark, and this mark should be a thread tied round the glass water gauge, and its position also noted by measurement above the fitting, in the event of slipping of the thread or possible breakage of the glass.

A very convenient method of water supply is to fix two 50-gallon bottles, above the pump supply tank, on a weighing machine, or each bottle may have a small and narrow neck with an overflow hole at the point where the contents are 50 gallons. Thus the correct amount can be filled in from taps above within a few grains every time.

The pump draught tank being started at a given level of about 50 gallons above its low water level, one bottle is run into the tank each time this becomes pumped down to low water level. When a boiler is working uniformly, the plottings of the water at each 50 gallons at the right place along a time scale will give a straight line not far from parallel with the plottings of each 50 lb. of coal supplied.

When water cannot be accurately measured, it is sometimes supplied by meter, and for uniform working a meter may give fairly comparative ratios, though it cannot be relied on for accuracy. On a test of engines as well as boilers the feed water is often assumed to be equal to the steam condensed and measured out of the air pump discharge of the surface condenser. In this measurement there will always be some inaccuracy from loss of steam at engine glands. The performance of the boiler as regards heat transmitted to the water is measured by the heat properties of water. The feed temperature is measured by a thermometer which ought to be placed in a mercury cup sunk in the feed pipe near the boiler. Usual practice finds a mercury cup on the inlet and outlet pipe of the economiser, and the outlet reading is taken as the boiler feed temperature. The specific heat of water varies with temperature, but may usually be neglected, for the steam tables found in most pocket-books will give the total heat per lb. of water at the feed temperature, and that per lb. of steam at the boiler temperature. The difference has been added in the boiler, and is given in thermal units, or B.Th.U. It will be correct except so far as the steam carries away some of the water as water, and lacking its several hundred units of latent heat. But what the discrepancy actually is cannot be told without some such methods as already outlined.

There has now been ascertained one item of heat expenditure. The total heat added in the furnace is the calorific value of the fuel, less such parts as escape unburned. The heat value of the fuel is found with fair approximation to accuracy by calculation from its composition.

The heat value of carbon is 14,647 B.Th.U. per lb. = 8,137 calories per kilogramme. That of hydrogen is 62,100 B.Th.U. = 34,500 cals. But in bituminous fuels the composition of the hydrocarbons is not known, and there is present oxygen in the form probably of water with some of the hydrogen, and such calculations are at best but close guesses. Goutel's formula is as follows:—

$$P = 82C + aV$$

where P = cals. in centigrade units, C = percentage of fixed carbon, V = percentage of volatile matter, a = a variable coefficient dependent upon the amount of ash and moisture.

Using the formula $V_1 = \frac{V \times 100}{C + V}$ the following values were found for a:—

V_1 =	5	10	15	20	25	30	35	38	40
a =	145	130	117	109	103	98	94	85	80

Probably all bituminous fuels follow much the same composition, but no compound fuel can be exactly calculated for calorific capacity, because hydrocarbons are endothermic or exothermic by nature, and have a heat value quite different from the sum of the heat values of their constituents hydrogen and carbon. The Bombe calorimeter of Mahler or Berthelot is, in good hands, a more accurate means of determining the value of a fuel.

To burn a fuel demands at least 8 lb. of oxygen per lb. of hydrogen, including the oxygen already present in supposed combination with some of the hydrogen. Each lb. of carbon requires 2·66 lb. of oxygen. The weight of air to be supplied is equal to the weight of added

oxygen multiplied by $\frac{100}{23}$, there being 23 parts by weight of oxygen per cent. of air. Thus the total air supply can be calculated from the analysis of the chimney gases. If a pure carbon fuel were burned it would require per lb. 11·6 lb. of air, and there would be 12·6 lb. of gas formed, of which 3·66̇ would be carbon dioxide or CO_2. The proportions are usually stated in volumes because analyses are volumetric, and for two volumes of CO_2 there will be $2 \times \frac{79}{21} =$ 7·524 volumes of nitrogen in the resultant gas, which will have a total volume of 9·524. Thus the CO_2 forms by volume almost exactly 21 per cent. of the total gas. When, as it always will, it forms a less percentage than this, the difference will be due to an excess of air. Thus if per lb. of carbon there are 19·048 total volumes of gas, this will be indicated by a percentage of carbonic acid only half the above, or 10·5 per cent. With hydrogen in the fuel the analysis cannot so easily be determined, for the hydrogen burns to steam which goes to water, and does not measure in a volumetric analysis. Yet some nitrogen remains from the air, which supplied oxygen to the hydrogen, and the total volume of gas is greater by that nitrogen, which goes to make the percentage of CO_2 appear less than it really is on its own account. There must be a suitable correction made for the hydrogen, and this being done, the total weight of the furnace products can be calculated from the analysis very closely; and since the temperature is known by aid of the thermometer, the total heat lost up the chimney may be ascertained.

The heat given to the steam and the heat carried off in the waste gases, and the heat given to the feed water if there is an economiser, combine to account for most of the heat capacity of the fuel. The ashes are weighed to find out their relative weight to the total fuel used. They are then well mixed together, all large lumps being crushed small and a sample taken by the system of quartering successively, the larger pieces being crushed at each step. When reduced to a final sample this is carefully levelled on a flat plate, and ten ounces separated out and carefully weighed and placed in a clean iron retort and heated to a clear red with access of air. The loss of weight when well burned gives the proportion of fuel in the ash, and enables the heat to be exactly calculated that has been actually generated in the furnace. Between the quantity of heat supplied and that found in the steam, and in the waste gas, there will be a discrepancy which is to be accounted for by errors of observation and by loss by radiation. This will be about 5 per cent. in the best cases.

Should the heat found exceed that supplied it may be variously explained. Often it will be due to water carried off as priming in the steam which has been assumed dry. This fault is often made to serve the ends of patentees who thereby magnify the virtues of their appliances. One of the chief errors in testing arises from the discrepancy between the condition of the fires at the commencement and finish of the test. This discrepancy has the greater effect in producing inaccurate results as the period of test is short. When both water and fuel can be weighed out in small lots, and the weighings plotted correctly on the time scale, the test will show clearly the action of the boiler while at work. Thus in a diagram, the curves of water and fuel are plotted on a time scale for each 50 gallons and 50 lb., the consumption being recorded as each water bottle is run out, and each 50 lb. coal bag finished. Such a method of testing shows the heat absorbent effect of the boiler brick-work. It shows how the boiler efficiency increases when the casing of brick becomes hot, and how the stored heat is finally utilised to some extent. It also shows the true boiler capacity under steady conditions.

In order to show the bad effects of leaking in of air through brick walls, samples of the gases from the back of a boiler, before the brick flues are entered by the gas, are taken simultaneously, if possible, with samples at each end of the economiser. They will show a progressive decrease of CO_2 towards the chimney, proving leakage of air, which by reducing temperature will reduce the heat transfer efficiency of the gases. Thus analysis points the need for air-proofing the seating walls either by enclosing in sheet iron, or by painting

with paint, or tar, or silicate of soda. The loss of heat and efficiency is greater than suspected, but a calculation may be made to show the difference between an air supply of 15 lb. and of 25 lb. per lb. of fuel. The extra 10 lb. of air rejected at 400° Fahr. above the atmospheric temperature has a specific heat of 0·24. It carries off, therefore, heat units $10 \times 400 \times 0{\cdot}24$ or nearly 1,000 B.Th.U. This represents 7 per cent. of the heat capacity of an average coal, and there are plenty of boilers at work with badly designed grates that are passing 20 lb. of air in excess of 15 lb. per lb., and throwing away 14 per cent. of the value of the coal more than ordinary good practice already compels to be wasted.

For making a boiler test under working conditions it is best to start the test after cleaning, as soon as the steam gauge reads the normal pressure, and the water level is then noted, and all subsequent coal and water is weighed. The test is finished under the same conditions of a made-up fire after cleaning, no attempt being made to secure a start, and a stop in even hours. The calculations can as easily be worked out in minutes with the slide rule, and this system obviates much guess-work. It is known as the flying test, and is probably more accurate and useful than the test started from an empty grate. The ashes are all cleared away at the start, and are similarly gathered at once on the signal being given to stop the test, when the water gauge glass should have been brought to level, and it only remains to gauge the water tank, and weigh back any coal left over from the last weighed-out portion.

The following figures are from a test on an express type boiler made under the author's direction.

They show the usual items sought by a commercial test. Such a test as this demands several assistants for easy working—one to attend to coal, one to check the water level, and one to take the gas samples. These are best taken by a continuous water pump of the Sprengel type, which draws a continuous sample of gas in a rapid stream while a second mercury draught bottle draws a small sample out of the flowing long sample. The mercury sample bottle contains the gas to be analysed, and it is clear that this sample forms an average of the so-called "long" sample which may represent the chimney gases for one, two, three, or more hours, as may be decided according to the slowness with which the mercury or short sample is allowed to require.

The boiler had a grate area of $9\frac{2}{3}$ square feet, a heating surface of 295·4 square feet, and a ratio of grate to heating surface of 1 : 30·6, which is very small for a small tube boiler, and shows the advantage of well-arranged heating surface, for the efficiency is by no means poor for this ratio. The fire-grate was of plain bars $\frac{15}{32}$ in. wide, and 29 bars went into a grate width of 27 inches.

The use of this test is that it showed the necessity for better air mixture, or a longer run of the gases before passing between the tubes in case of the draught being what it was. Less carbonic oxide was made when the air was increased in quantity, but the efficiency was less. Thus with only 0·68 of CO and 12·52 per cent. of CO_2 and 30·3 per cent. of surplus air the efficiency was 61·1 per cent. It fell to 58 per cent. on a third test with 10·7 of CO_2, 0·28 of CO, and 41·32 per cent. of excess air, showing clearly the bad effect of excessive air, and the benefit that would have been got from better mixture.

Seven Hours' Test of Express Water-Tube Boiler.

General Data.

Duration of trial	7 hrs. 10 min.
Weather	Fine.
Barometric pressure—lb. per sq. inch	14·3
Mean boiler pressure per standard gauge—lb. per sq. inch	134·4
Mean boiler pressure per standard gauge. Absolute—lb. per sq. inch	148·7
Corresponding temperature of saturated steam °F	357·5
Observed temperature of steam °F	357·3
Character of steam	Saturated.

Feed Water.

Mean temperature of water in measuring tank - - °F	63·2
Mean temperature of water in feed tank - - - - °F	120·8
Total weight of water supplied to boiler - - - - lb.	23,188
Total weight of water supplied to boiler per hour - - lb.	3,229
Weight of water evaporated per hour per square foot of heating surface - - - - - lb.	10·93

Coal and Ashes.

Description of coal	Nixon's Navigation.
Moisture removed at 212° per cent.	1·88
	Per Hour.
Weight of coal as fired - lb.	2,800
Weight of coal as dry - - lb.	2,747.438
Weight of ash and unconsumed carbon - - - - - lb.	149½
Weight of combustible burnt lb.	2,597·9
Weighed ash and unconsumed carbon - - - per cent.	5·44

Temperature of Air.

Mean temperature of external air in shade - - - - - °F	63·3
Mean temperature of air in Boiler House - - - - - °F	77·8

Temperature of Gases.

Mean temperature of gases in 23 observations - - - °F	747·5
Probable mean temperature on 19 occasions when above 850° °F	900
Final mean probable temperature of gases in funnel - - °F	814
Mean draught in funnel water column - - - - - -	·91″

Analysis of Gases of Combustion.

Carbonic acid - - - - -	12·66
Carbonic oxide - - - - -	1·17
Oxygen - - - - - -	5·54
Nitrogen - - - - - -	80·63
	100·00
Equivalent to gases of combustion	73·38 °/₀
Surplus air - - - - - -	26·62
	100·00

Analysis of Dry Coal.

Carbon - - - - - -	86·27
Hydrogen - - - - - -	3·89
Oxygen - - - - - -	3·58
Nitrogen - - - - -	0·64
Sulphur - - - - - -	1·07
Ash - - - - - - -	4·55
	100·00
Moisture removed when dried at 212° - - - - - -	1·88

Heat Available in Furnace per lb. Dry Coal.

Obtained in Calorimeter—British Th. Units - - - - -	14,976

Analysis of Cinders.

Real Ash - -	(°/₀ weight)	58·50
Unconsumed carbon	do.	41·50
		100·00

Gases, Air and Vapour.

Weight of gases produced, per lb. dry coal - - - - - lb.	11·78
Weight of surplus air - - lb.	3·88
Weight of water vapour in air lb.	·17
Weight of steam from water in coal, per lb. dry coal - lb.	·02
Weight of total gases, air and vapour, per lb. dry coal - lb.	15·85
Capacity for heat of gases, air and vapour, per lb. dry coal—British Th. Units - - - - -	3·89

Combustion.

Weight of dry coal fired per hour per sq. ft. of grate - lb.	39·6
Weight of dry coal per sq. ft. heating surface - - lb.	1·296

Evaporation.

Weight of water evaporated at observed mean temperatures per lb. dry coal fired - - lb.	8·42
Factor of evaporation - - -	1·141
Equivalent evaporation from and at 212°	
a. Calorific value of dry coal -	15·51
b. Obtained per lb. dry coal fired - - - - - -	9·61

Efficiency.

Efficiency of Boiler - - -	62·0

HEAT BALANCE SHEET.

Appropriation of Heat in Boiler.

	B.Th.U.		Per Cent.	Totals.
Heat imparted to water in boiler - - -	9,280		62·0	...
Heat carried away by products of combustion -	2,535		16·9	62 °/₀
Do. do. surplus air - - -	694		4·6	...
Do. do. vapour contained in air -	60		·4	...
Do. do. steam from water in fuel -	27		·2	...
Heat carried away by total gases, air and vapour -	...	3,316	...	22·1 °/₀
Heat lost by imperfect combustion - - -	718		4·8	...
Do. unburnt carbon in ashes- - -	331		2·2	...
Do. ashes, drawn from furnaces - -	10		·1	...
Do. radiation and unaccounted for -	1,316		8·8	...
Do. total sundry - - -	...	2,375	...	15·9 °/₀
	14,971		100·0	100·0

Boiler Test Pump.—A force pump operated by a hand lever, used for putting the hydraulic pressure into a steam boiler after the boiler has been nearly filled from a hose pipe. As it is not required for filling, but only for the final pressure, it is not of large capacity, and it is provided with a pressure gauge for indicating the test pressure exactly.

Boiling. — When heat is applied to the bottom of a vessel containing a liquid such as water there is a continual displacement of the liquid particles; those near the bottom which are first heated, expand, and thus becoming specifically lighter than the other particles, ascend; colder particles occupy their place, and becoming heated ascend in their turn; thus a current is established in which the heated particles rise up through the centre and colder particles descend at the sides. By continuing the process the liquid particles are not only displaced, but converted into steam. As these bubbles of vapour rise into the colder portion of the water they are condensed, thus producing the familiar "singing." When the temperature of the water above is too high to condense these bubbles they rise to and escape at the surface. Ebullition then takes place and the water "boils." When the boiling point is reached the temperature of the liquid ceases to rise, the thermometer remaining stationary.

The boiling point of a liquid, however, does not depend upon the temperature but upon the *pressure* to which it is exposed. This is strikingly shown in the following experiment:— A flask filled about one-third with water, is placed over a flame until the water boils; the steam issuing from the neck of the flask will expel the air, and while the steam is thus issuing, an accurately-fitting cork is inserted. The flask is now set aside for a few minutes, until it has cooled considerably; it is then immersed in cold water contained in a glass vessel, when the water in the flask will begin to boil again with a violence proportionate to the coldness of the water. This experiment admits of easy explanation. When the flask is plunged into cold water, it is two-thirds filled with steam; the cold immediately condenses this into water, leaving a vacuum and consequently no pressure above. The heat left in the water is sufficient to make it boil, and it continues to do so until the vapour formed above it exerts a pressure sufficient to prevent any further ebullition at the temperature of the flask. If, however, the flask be plunged into ice-cold water the steam will be again condensed, and the boiling will go on as before. Thus by diminishing the pressure we lower the boiling point, and by increasing the pressure the boiling point becomes raised. In a mine, water boils at a higher temperature than 212 degrees

(the boiling point under ordinary pressure), and is consequently hotter than it would be at the surface. On the other hand, the higher we ascend the lower is the temperature of the boiling point. On the summit of Mont Blanc, Saussure found that water boiled at 187 degrees, while explorers often find it impossible to cook food or boil eggs at great heights—even though the water be vigorously boiling. (By means of the instrument known as the hypsometric thermometer the height of mountains may be ascertained by noting the boiling point of water, a difference of 1 degree Cent. indicating roughly a distance of 1,080 feet.) The laws, then, which govern the boiling of liquids may be summarised as follows :—(*a*) A liquid boils when the pressure of its vapour becomes equal to the pressure of the atmosphere (or, the pressure to which it is exposed). (*b*) By increasing or decreasing the pressure the boiling point is raised or lowered; each liquid possessing a definite boiling point for a definite pressure.

If water be heated in a closed vessel its own vapour accumulating above it will obviously increase the pressure and so raise the boiling point and the temperature. Papin's Digester is based on an application of this law; it consists essentially of a strong boiler partly filled with water and possessing a tightly fitting cover which is screwed down. The steam which is generated greatly increases the pressure above the water and so raises the boiling point as high as 400 degrees, and is thus capable of extracting the gelatine from bones. Of course a safety valve is fitted to the Digester, and it is claimed that it was in this apparatus the safety valve was first used.

Boiling.—Better known as pig boiling or wet puddling as distinguished from the dry process of making malleable iron. *See* **Puddling.**

Bolster.—A seating on which punching or stamping is done.

Bolt.—In its various forms the bolt is employed in practically all classes of mechanism for the attachment of parts. With one exception,—the cotter type,—all bolts operate through the medium of screw threads which may be of any of the standard forms. For these *see* **Screw Threads.** The bodies and especially the heads are subject to much diversity in shape, to suit varying classes of service.

The commonest forms with square head and nut, A, Fig. 2, and hexagon ditto, B, are employed in innumerable cases, the square head for woodwork and the rougher classes of machinery,

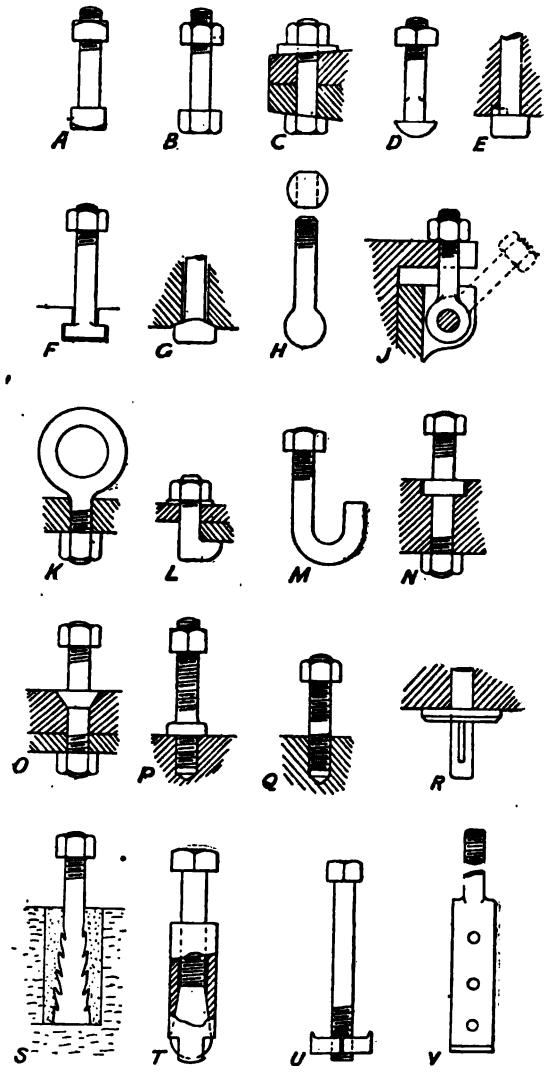


Fig. 2.—Forms of Bolts.

and the hexagon for better work, especially where limited turning space for the spanner renders the hexagon desirable, for reasons which are explained under **Spanner.** The accompanying table gives particulars of Whitworth bolts and nuts up to 3 inches diameter.

WHITWORTH STANDARD BOLTS AND NUTS.

Size of Bolt and Thickness of Nut.	No. of Threads per Inch.	Diameter at Bottom of Thread.	Area at Bottom of Thread.	Thickness of Bolt Head.	Nut Across Flats.	Nut Across Corners.
In.		In.	In.	In.	In.	In.
1/8	40	·093	·0067	·109	·338	·390
5/32	24	·134	·0141	·164	·448	·517
3/16	20	·186	·0271	·219	·525	·606
7/32	18	·241	·0456	·273	·601	·694
1/4	16	·295	·0683	·328	·709	·819
9/32	14	·346	·0940	·383	·820	·947
5/16	12	·393	·1213	·437	·919	1·06
11/32	12	·456	·1633	·492	1·011	1·16
3/8	11	·508	·2026	·547	1·101	1·27
13/32	11	·571	·2560	·601	1·201	1·38
7/16	10	·622	·3038	·656	1·301	1·5
15/32	10	·684	·3674	·711	1·39	1·6
1/2	9	·733	·422	·766	1·479	1·7
17/32	9	·795	·496	·820	1·574	1·82
1	8	·840	·554	·875	1·670	1·95
1 1/16	7	·942	·697	·984	1·860	2·15
1 1/8	7	1·067	·893	1·094	2·048	2·36
1 3/16	6	1·161	1·057	1·203	2·215	2·55
1 1/4	6	1·286	1·29	1·312	2·413	2·78
1 5/16	5	1·369	1·47	1·422	2·576	2·97
1 3/8	5	1·494	1·74	1·531	2·758	3·18
1 7/16	4½	1·590	1·99	1·641	3·018	3·48
2	4½	1·715	2·31	1·75	3·149	3·63
2 1/16	4½	1·840	2·66	1·859	3·337	3·85
2 1/8	4	1·930	2·92	1·969	3·546	4·09
2 3/16	4	2·055	3·31	2·078	3·75	4·33
2 1/4	4	2·180	3·73	2·187	3·894	4·49
2 5/16	4	2·305	4·17	2·297	4·049	4·67
2 3/8	3½	2·384	4·46	2·406	4·181	4·82
2 7/16	3½	2·509	4·92	2·516	4·346	5·02
3	3½	2·634	5·44	2·625	4·53	5·23

Where the face of work is not at right angles with the bolt hole the head must be bevelled C, or alternatively a sloped washer may be used, as shown under the nut. The latter having to be rotated, the washer is a necessity. To prevent bolts from turning as the nut is revolved several methods are in use; the head may be sunk into a recess fitting it closely, so that turning is impossible. This is frequently done in ordinary work, especially for square heads. Another plan is to form a square neck upon the bolt D, fitting in a square hole in the object, a method used both for wood and metal. For the better classes of machines a plug driven in under the head serves to prevent rotation, a recess being chipped or cut out to receive the plug. The bolt head E is then often made of circular shape, being finished wholly by turning. The tee head F is also designed to prevent revolution, and is employed chiefly in cases where it is convenient to slide the bolt endwise along a slot. For machine tool service this form is used almost exclusively, being the type best suited to the peculiar needs of clamping work and tools.

It is sometimes necessary that a bolt shall pivot or swivel to accommodate lateral movement, if the face upon which the nut bears is not square. A small amount of movement is met by the convex headed bolt G fitting in a recess. The hole is made to clear the body, thus allowing the necessary side play. The nut also is frequently convexed, or is provided with a convex washer. The ball bolt H allows of still more play than the preceding one. The eye bolt J is pivoted upon a pin so that it may be thrown back out of the way, after the nut has been loosened. This is a valuable feature in certain jobs, where, for instance, a joint has to be taken apart and put together frequently. The time otherwise occupied in running a nut right off, and removing the bolt is saved, because the swinging out of the way (as shown dotted) is sufficient to free the attached piece—a slot in the latter allowing the bolt to fall outwards. The other form of eye bolt, K, employed for lifting purposes is either simply screwed into the work, or passed through and held with a nut, as shown.

The hook bolt L is useful in cases where it is impossible or undesirable to provide a hole in one portion of work, the head being turned round at right angles to clip the face. Ready removal is the chief advantage of this type. A variation of the hook, the hanger M is employed chiefly for supporting pipes and rods, &c.

The collar bolts N and O are used where it is necessary that the bolt shall remain fixed in place, which is notably the case in stuffing box and gland work, and in plummer blocks with removable caps. The bolt may be either simply fixed in one casting, as at N, or it may hold two pieces together as at O, while still

leaving the upper nutted end free for the attachment of a third piece. The pillar bolt P is also employed where a fixed type is required, being screwed into the base piece.

These types bring us to the stud bolt Q which is fitted where either there is no rear face to take a head, or when it is necessary to have the bolt held in a fixed position. For such work as cylinder covers, the advantage of having all the bolts immovable when the covers are being taken off or replaced is very apparent, and results in much saving of time.

Three types which are extensively adopted in foundation and wall work are the cotter R, the jagged S, and the expansion T. The first-named form is used for convenience, as the removal of the cotter at once frees the bolt—a method preferable to unscrewing a nut in awkward situations. Cheapness is also a consideration since there is no screwing, but forging only, for common work. The jag bolt is held by liquid grouting poured around it and allowed to set. The expansion bolt is a special kind for masonry, the act of screwing up the bolt forcing open the casing or shield and jamming it into the stone. The fang bolt U is adopted for the attachment of wood to metal work, the spiked nut, of large area, sinking into the wood and affording a good grip, while the head is revolved. The strap bolt V has a long flat tang forged with its end bent round; it is used chiefly for attachment to timber and to walls, the tang being employed as a kind of anchorage.

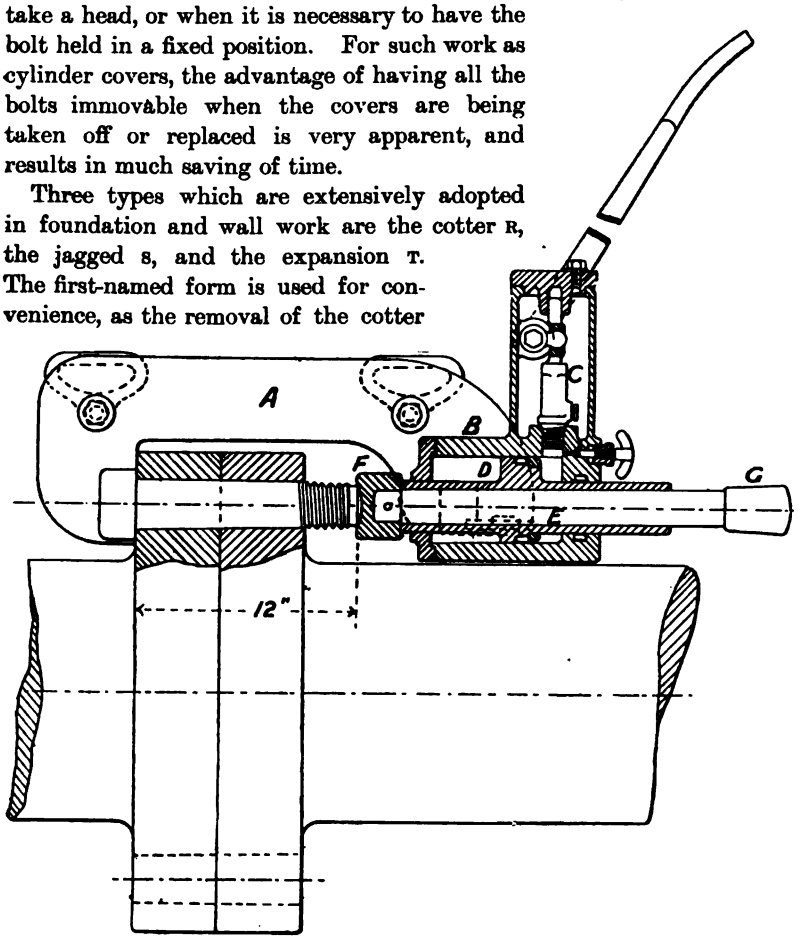


Fig. 3.—Bolt Forcer.

The style of fitting followed for bolts depends upon the class of work and the service which they have to perform. The question of black, and of bright or turned bolts is settled by cost and necessity. For work where there is no pretence at very accurate fitting black bolts, *i.e.*, simply forged, fitting in cored holes are quite adequate, though precise location of pieces is often insured by putting in a small proportion of turned bolts in reamed holes sufficient to prevent the parts from lateral displacement. For the better classes of jobs nothing but turned bolts are used, fitting closely in their holes, and the side strain on them is frequently relieved by the provision of tongues or shoulders on the work. Bolts are finished by turning the body, and facing under the head only, or by brightening the head all over, and sometimes hardening, the cost being correspondingly enhanced.

The nuts used on bolts are either of square, hexagon, or circular shape, the last named being used where neatness and avoidance of sharp corners are desirable, such as in revolving spindles. Holes are either drilled in the nut to receive a tommy, or slots are cut, and a special kind of hooked spanner used.

Standard nuts are of a thickness equal to the

diameter of bolt; for special work, as where great pressure is met, or very frequent handling is done, the nut may be one and a half times or twice the bolt diameter.

Flanged nuts are made in one with a washer, to cover holes which are considerably larger than the bolt diameter. Box or cap nuts are blank ended and are adopted where rusting is liable to occur. They are generally cast in brass. The subject of lock-nuts will be found under that heading.

The strength of bolts is not so simple a question as may appear at first sight. The simplest case that can occur is that of tension in an axial direction; the bolt strength would then be that of the metal in tension, but the work of screwing up the nut introduces an incalculable factor, since the thread may be stripped by the exercise of too much force. This again opens up the question of the sectional forms of screw threads, under which head the subject will be found treated. It is usual in practice to allow a unit load on bolts, to which the area under the thread is correlated. This stress or load ranges from 2 tons to about 6 tons per square inch. Tables of this kind are prepared and hung up for use in drawing offices.

Bolt Forcer.—The function of this is to effect the removal of tightly fitting bolts, such as in propeller shaft couplings, &c., where hammering alone is ineffective and damaging. The forcer, Fig. 3, by Messrs Youngs, which is shown at work on a coupling, has two hook frames A (one is seen in the half-section), the inner edges of which take their bearing against the coupling face, the bolt head lying between the frames. The other end of these carries a hydraulic cylinder B, and hand pump C. Inside the former is a hollow ram D, which encircles a drift E having a cap F at the end. When the pressure is put on the pump, the ram forces the cap against the bolt tail. Should this be insufficient to start the bolt (which perhaps is rusted in) a few hammer blows are delivered on the end G of the drift, which it will be noticed is free to slide in the ram D. After thus starting, the bolt may be ran out by pumping or by hammering. These forcers are made in six sizes, from 20 up to 75-tons power. The illustration is that of a 30-ton machine, admitting 12 inches between the cap F and the frame end. The 75-ton type accommodates 18 inches between.

Bolt Cropper.—A tool used for cutting off bolts and rods up to about $\frac{5}{8}$ in. diameter. The jaws are closed by a system of toggles, giving great power, in combination with the leverage afforded by the long handles.

Bolt Cutter.—*See* **Bolt Screwing Machine.**

Bolt Making.—The majority of bolts are produced by forging methods, although for some work the turret lathe or automatic screw machine is employed, reducing from a bar of the size of the head. The head, if other than circular, is subsequently milled to shape. Drawn hexagonal and square bar is used for much work, the body being turned down therefrom, so that no machining of the head is required.

Bolts are forged in three different ways:—A ring may be welded on to a bar to make the head; the latter can be formed by upsetting; or swaging may be done, from bar the size of the head. In the first case the head is prepared from rectangular bar, cut off and bent round into ring shape. This is then slipped on the bar and welded, subsequent finish being imparted in swages or in dies, giving the final form of head, square, hexagonal, or otherwise. The upsetting method is followed very extensively, being quite suitable, provided the metal is coerced sideways in dies to counteract the splitting tendency, and numerous machines are constructed both of horizontal and vertical forms for the production of work on this system. One of the latter by the Tangye Tool & Electric Co., Ltd., is shown in Fig. 4. It has two rams A, A, working in guides fitted with adjusting strips, so that slack may be taken up. Each ram is reciprocated by an eccentric pin on the ends of the main shaft B. The latter is driven through the fast and loose pulleys and spur gears, a flywheel being placed on the pulley shaft. The flywheel and pinion are connected with bolts which shear in case of undue strain coming upon the machine, and so prevent damage.

The tables carry the bottom dies in a manner which permits of easy insertion and removal of work; the cast-steel die-holders C, C, slide in vees in the frame, upon steel facings, so that C, C

may be drawn back by the levers, actuated by the handle D, seen only at the right-hand side. The piece of bar is placed in the die, the latter slid forward under the ram, and again withdrawn after stamping, to remove the bolt. The latter is first lifted up automatically by the rise of the ram A; this has a tie rod E connected to a lever G which is pulled up under an ejecting rod H sliding in C, and retained therein by a cottar. A detail of the dies is given separately in the upper part of Fig. 4. They are of cast iron, and held with set-screws. The rod H is seen underneath the bolt just headed.

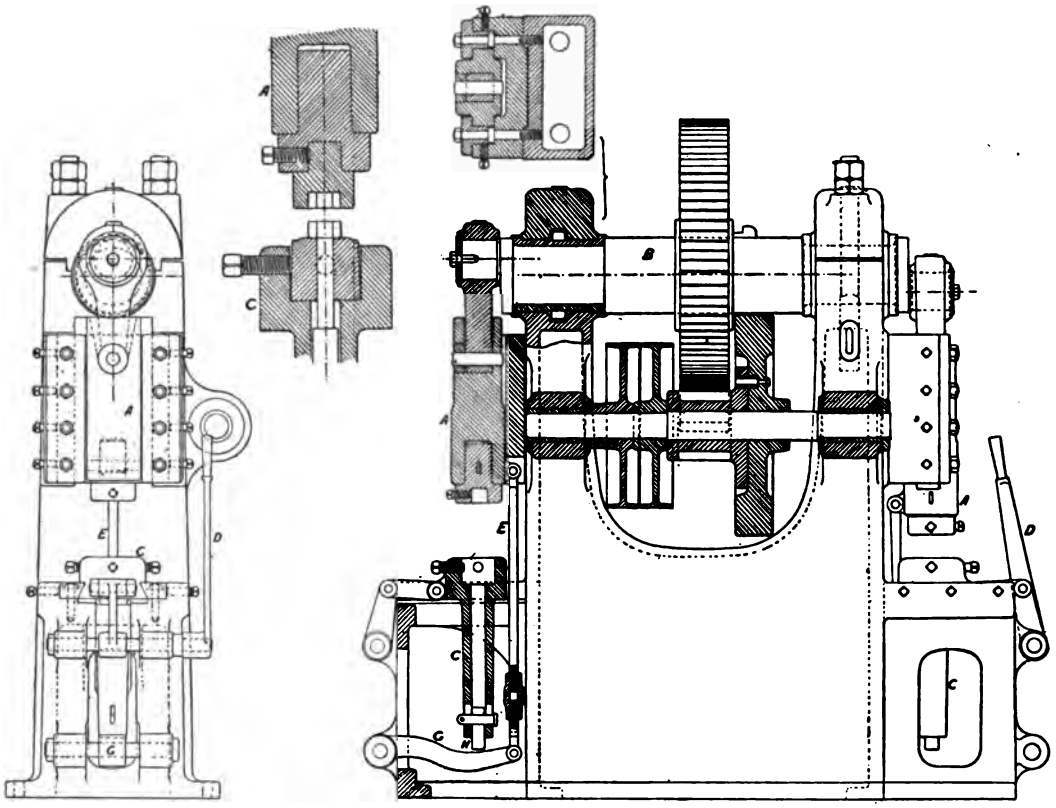


Fig. 4.—Bolt Forging Machine.

Other machines in which forging is done are the horizontal **Heading Machines**, and the various drop hammers and presses, such as are employed for die forging.

The swaging method is less practised than formerly for regular bolt manufacturing, due to the increasing use of the heading method. It is done either with fullers on the anvil, or in dies under the power hammers, or **Forging Machines**, having a graduated set of dies for the reduction of the bar by stages.

Bolt Mandrel.—*See* **Mandrel.**

Bolt Oliver.—*See* **Oliver.**

Bolton Hoop.—The same as Bowling hoop, described under **Furnace Flues.**

Bolt Screwing Machine, or **Bolt Cutter.**—Detail drawings of a typical design, the "Brown," by John Stirk & Sons are given in Figs. 5 and 6. It is of the type in which the bolt is held while the dies revolve, and draw the bolt along through them. A is the driving cone, —four-stepped, transmitting motion through the double set of spur gears to the spindle B, which is hollow, and carries at its outer end the die-head C, opened and closed by the handle D, the method of which will be considered in connection with Fig. 6. The work is gripped

in the carriage E, racked along the bed by the handwheel F. Vee-jaws G, G, are opened or closed by the right and left hand screw, operated by handle H. The opening of the die-head is performed automatically as the carriage is travelled up by means of the striking rod J, on which a small stop collar is pinched where desired. The collar is struck by the carriage, and jerks the rod J along, moving the lever K, which has an arm that strikes the balanced end of D, and throws the latter over.

Details of the opening die-head are seen at Fig. 6. The sliding collar C has a ring held

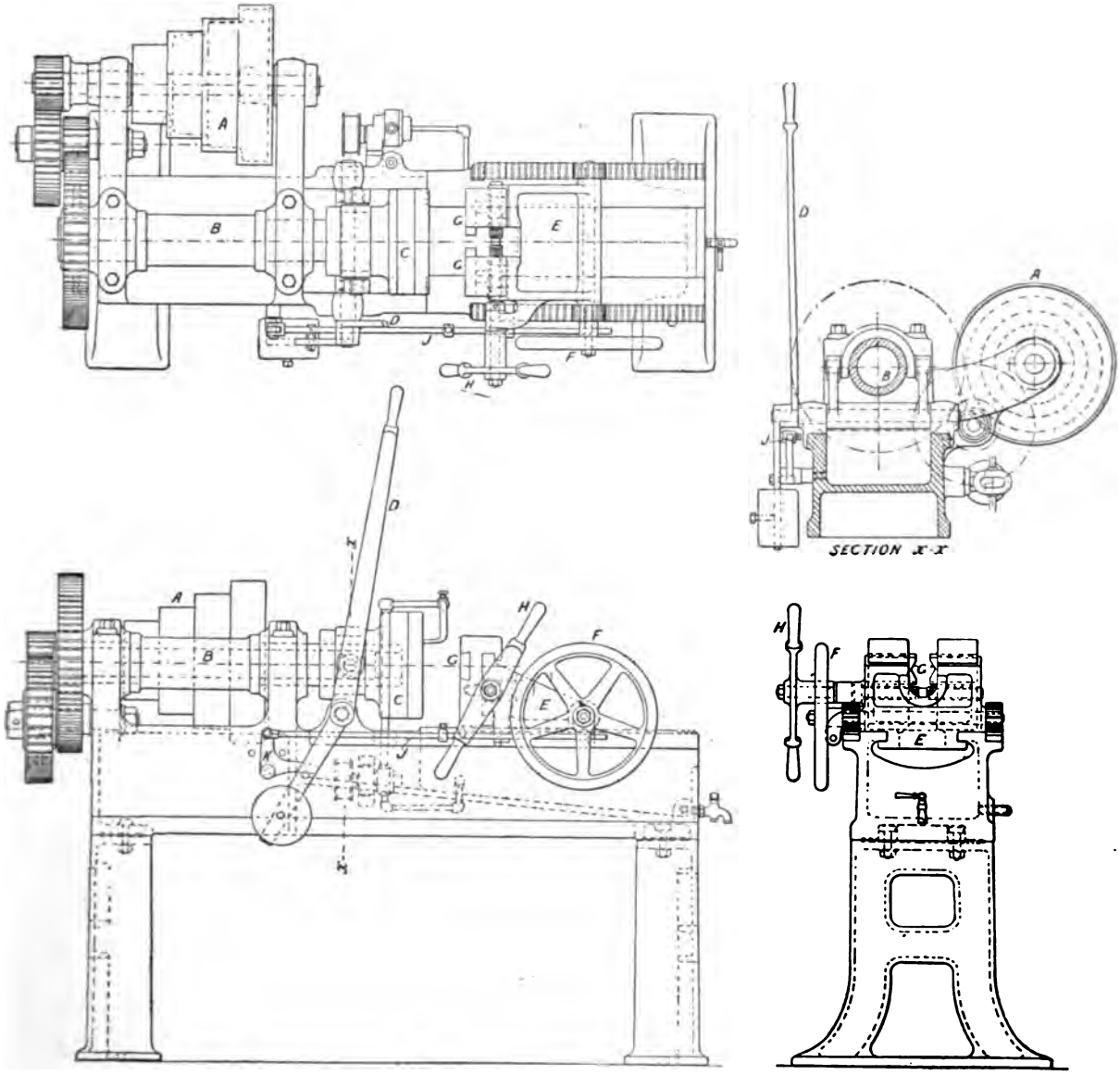


Fig. 5.—Bolt Screwing Machine.

to it with tee-slot bolts, and a ring *b* is screwed to this; *b* has coned grooves, *g*, laid out in cam fashion, as seen in the view to the right, and these control the circumferential movement of the dies, *c*, closing them in, or allowing them

to travel outwards, under the pressure of the band spring, *d*, shown by thick black lines, which enters into slots cut in the dies. The latter slide in grooves slotted in *f*, screwed to the spindle of the machine. A cover plate *e* retains the dies in place, while still allowing them to slide. A pump is provided for the ample lubrication of the dies, the bed being formed into a reservoir. The machine has a capacity up to 2 inches, and dies may be fitted for the sizes, $\frac{1}{2}$, $\frac{5}{8}$, $\frac{3}{4}$, $\frac{7}{8}$, 1, $1\frac{1}{8}$, $1\frac{1}{4}$, $1\frac{1}{2}$, $1\frac{3}{4}$, and 2 inches.

Bolt-screwing machines of this design are made in special types by various firms. Very long beds are sometimes provided for lengthy work, as tie bolts. Double or treble heads and bolt carriages are fitted to one bed, so that a single operator can look after what amounts to three machines. In cases also where great accuracy is required, or long threads have to be cut, a lead screw is provided to take the carriage up at the correct rate, and so avoid dragging of the dies on the work, which tends to produce incorrect threads. The design of machine illustrated above constitutes the larger class made, but another type has the die-head on a travelling carriage, which causes the dies to run along the work, instead of *vice versâ*.

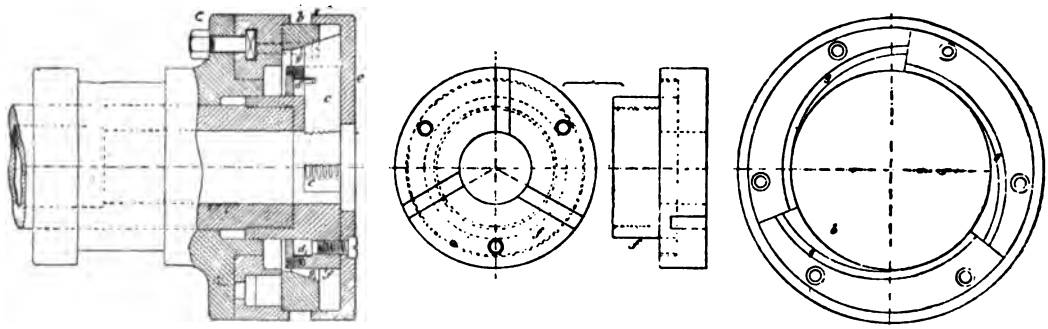


Fig. 6.—Dies for Bolt Screwing Machine.

Bonding or **Banding**.—Denotes in general the securing of objects by an encircling bond of metal strip. It is applied to the bonds that encircle the lagging of steam boilers, and of cylinders; to the fastening of compressed materials, and similar operations; and to the reinforcements of weak tubes by rings shrunk on.

Bones.—Used in **Case Hardening**.

Bonnet.—The hood of a smith's forge, or the removable cover which confines a pump valve in its seating, or a cowl, or a hood over a ventilating pipe.

Bonneted Safety Valve.—A steam safety valve covered at the top with a hood to prevent diffusion of escaping steam into a building. A waste-pipe comes from the bonnet to convey the steam away outside.

Bonus.—Something paid over wages when a piece of work has been done more expeditiously than usual. It is sometimes paid as an incentive in day work systems in preference to piece-work. The Bonus system is an extension of this old practice, and will be found described under **Premium System**.

Book-keeping.—The injunction "put all in writing that thou givest out or receivest," in the Book of Ecclesiasticus, and the fact that bricks have been excavated in the ruins of Babylon bearing tabulated records of financial transactions, prove that some system of book-keeping was appreciated and practised in the early days of trade and commerce. But it was not till the end of the fifteenth century that it was systematised in its present form by the great merchants of Venice, and in 1495 Lucas de Burgo published a treatise in the Italian language. The "Italian Method," as it was called then, spread to other European countries, and the modern method of double entry is practically based on this Italian system.

There are two systems of book-keeping in use, single entry and double entry. The former is an incomplete and slipshod method suited only

for very small businesses. It merely takes account of the persons dealt with, and each transaction is given but one entry, so that frauds or errors in these entries cannot be checked, neither can the sources of profit and loss be readily ascertained, nor comparisons be made between different sections or departments. The method of single entry then deserves mention only for condemnation.

The system of double entry is based on the fact that every receiver implies a giver, every debtor a creditor, and every buyer a seller; he who receives is the debtor, he who gives is the creditor, and every debit must have a corresponding credit. Thus, if Smith & Co. buy £100 worth of pig iron from Clark & Son, the latter firm will have £100 placed to the credit of their account in the ledger, while, as goods are received, Messrs Smith & Co. will place £100 to the debit of their Goods account. Thus, for every transaction the receiver is debited and the giver credited, and in an accurately posted ledger the sum of the debits must be equal to the sum of the credits. A thorough grasp of these facts forms the key to this system of double entry. The abbreviations Dr. and Cr. are used for debtor (or debit), and creditor (or credit) respectively, the left-hand half of a ledger folio being the Dr. side, and the right-hand half the Cr. side. While the accounts in single entry deal only with persons, those in double entry are impersonal, *i.e.*, cash, iron, &c., are treated as though they were parties carrying on transactions. Thus if a firm spends £750 on goods, that amount is posted to the debit of Goods, and if the firm receives cash, the amount is debited to Cash.

The number of books used in keeping accounts varies with the size and nature of the business, but the Day Book, Invoice Book, Journal, Ledger, and Cash Book may be considered as the minimum necessary to keep a proper system of accounts.

The Day Book, or Sales Book as it is sometimes called, contains the record of each day's sales. The name of the purchaser is entered, a description of the goods and the amount. At intervals the Day Book is posted into the Ledger, debiting each personal account and crediting the Goods account.

The Invoice Book, which records purchases, is entered up in the same manner as the Sales Book. In posting, the totals are placed to the credit of the account of the firms from whom goods are bought, and to the debit of the Goods account.

The Journal may be regarded as one of the most important of the books used in the double entry system, second only in value to the Ledger. The miscellaneous and unclassified transactions roughly recorded in the other books are systematically arranged in this one, thus facilitating transfer to the Ledger. This process is referred to as "journalising."

The Ledger is posted from the Journal and contains exactly the same entries, but each account is here isolated and dealt with under its own heading, persons, goods, wages, rent, profit and loss, each having a separate account. As every debit implies a corresponding credit, each entry on either side of any account demands a similar entry on the opposite side of some other account, and so, if posting has been correctly done, the grand totals of all the credits and of all the debits should be exactly equal to each other and also equal to the totals in the Journal.

The Cash Book contains a record of all cash transactions, amounts received being placed on the debit side, and amounts paid out on the credit side. By totalling these two sides the exact amount of cash balance may be ascertained at any moment. Entries in the Cash Book are generally transferred direct to the Ledger and not posted through the Journal.

The number of subsidiary books used varies in different businesses, but among the more important of these minor books are:—the Petty Cash Book, containing an account of minor expenses too small for separate entry in the Cash Book; the Bill Book for details of bills receivable and bills payable; the Return Book for particulars of goods returned to the firm and by the firm; the Order Book in which all orders are recorded; and the Wages Book.

Boom.—The upper and lower flanges of built-up girders for bridges and gantries are so termed. The jib of a derrick crane is often termed a boom.

Borax ($Na_2B_4O_7 + 10H_2O$) is a sodium

compound of the element Boron. It is found native, under the name of tincal, and exported from Tibet, California, Peru, and Persia. Large quantities of borax are now obtained, however, from the volcanic districts of Tuscany. Steam and vapour, impregnated with boric acid, escape in jets from fissures in the earth and the volcanoes; the boric acid collects in artificially constructed lagoons, passing through a series of them until it becomes so concentrated as to form crystals, in which state it is exported to the extent of about 2,000 tons per annum. These crystals are mixed with sodium carbonate and heated, the salt being then dissolved and crystallised. Borax crystallises from its aqueous solution in prismatic or octahedral crystals, the former containing 10 and the latter 9 equivalents of water. By adding strong sulphuric acid to a boiling solution of borax, boric or boracic acid is obtained; on cooling, crystals (H_3BO_3) separate out.

Borax is of great value owing to its property of dissolving metallic oxides. In the process of soldering oxidisable metals it is sprinkled over the surfaces to be united, where it fuses, and dissolves the oxide which would render adhesion impossible. *See* **Brazing**. In addition to its use as a preservative of meat, milk, butter, &c., its antiseptic properties are of value in medicine. A varnish for the stiffening of hats is also made with one part of borax and five of shellac. Yet other uses to which it is put are the glazing of pottery, the manufacture of artificial gems, the making of laundry glazes, and the manufacture of enamel. In the laboratory, borax is useful in blowpipe tests. A loop of platinum wire is heated and dipped in powdered borax, and on reheating, a colourless and transparent bead is formed. A small portion of the substance under examination is placed on it and heated in the flame, and the resulting "borax bead" gives a characteristic colour. Thus copper gives a green colour; Ag_2O, ZnO, PbO, &c., grey; CoO, blue, and so on.

Bore.—The term signifies in general a hole, whether it is produced by actual boring or not. Thus the bore of a pipe is a cored hole, but with few exceptions a hole that is tooled is understood, as the bore of a cylinder, or pump, or brass, or that of a well produced by boring tools.

Bored Holes.—So termed in the shops to distinguish them from cored holes.

Bore Hole Pump.—Denotes a pump used for deep well work, hence often termed a deep well pump, or deep lift pump. It may be either single, or double acting. The working barrel which contains the buckets is sunk in the well below the lowest water level, or within from 15 to 20 feet of the surface of the water. The buckets are connected by lengths of rod to the pump plunger above. The latter is either set entirely above ground, or in a "well" at the top of the bore hole, just below the ground level, as in Figs. 11 and 14. Such pumps are driven either by steam, oil, or gas engines, or electric motor, or belt, or by horse gear as most convenient. Around this broad design very many details of construction are found in the practice of different firms, and differences in the conditions under which the pumps are used, and in cost. Some of the principal among these may be briefly noticed.

The chief differences are found in the forms of the buckets and the working barrels. The barrels are properly made of gun-metal, but they occur also in solid drawn brass for small pumps, in cast iron, and in mild steel. The barrel is screwed at its upper end to the rising main. It receives a foot valve at its lower end, with, or without a strainer. In the illustrations, Figs. 11 and 14, both the foot valve and the pump bucket are provided each with four annular seatings, involving, therefore, but a small lift to the valve, and reducing the concussion and wear to a minimum. In a double-acting arrangement, a more steady and larger delivery of water results, and the parts are better balanced. It is necessary to have buckets with considerable length of wearing surface. In one of Hayward Tyler & Co.'s types the bucket is therefore prolonged into a guide, and recessed for a "water ring" which takes the place of the usual leathers. For long strokes and deep lifts they have a yet longer bucket, with two or more cup leathers, and a common lift valve with mitre joint.

There are other forms which are illustrated, each designed for special duty, for larger or smaller valves, deeper or shallower wells.

As wells go deeper, smaller working barrels

are generally required, and of greater strength, and this explains why pump details suitable for comparatively shallow wells are not so for deeper ones.

The rising main is usually, and properly larger in bore than the working barrel in order that the bucket and foot valve can be drawn to the surface without disturbing the main. Sometimes in shallow wells the proportion is reversed, for the sake of economy. In such a case the rising main and the working barrel must be drawn up before the buckets can be removed. This is only suitable for temporary service.

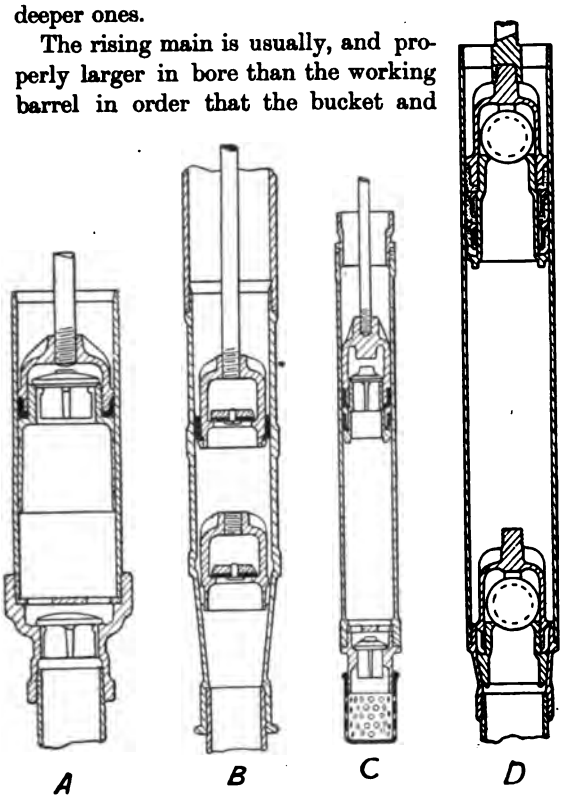


Fig. 7.—Barrels and Valves for Bore Hole Pumps. (Hayward Tyler & Co., Ltd.)

The following illustrations from the practice of Messrs Hayward Tyler & Co., Ltd., will give a good idea of the variations which are found desirable or necessary in the designs of deep well pumps.

Fig. 7 A is a type of barrel suitable for moderately low lifts, or from 100 ft. to 160 ft. It is of brass, with mitre valves, and having water rings or double bucket leathers; diameters in this type range from 2 in. to 6 in., and lengths of stroke from 6 in. to 10 in.

Fig. 7 B is a standard type suitable for lifts from 120 ft. to 250 ft. The valves are of the common clack type, faced with leather. The bottom valve can be lifted with a screw rod. All parts are of brass and gun-metal.

Fig. 7 C is a design for long strokes and total lifts up to 250 feet. The barrel is of brass, and the bucket of gun-metal, as is also the suction valve. The bucket is of good length, with two cup leathers. These are made in diameters of from 2 in. to 4 in., and in length of stroke from 10 in. to 22 in.

Fig. 7 D is a type of barrel used for the deepest wells in which the bores must necessarily be small, the diameters in this style ranging only from $1\frac{3}{8}$ in. to $4\frac{3}{4}$ in. The ball valves used here are not found suitable for bores larger than $4\frac{3}{4}$ in. The bucket is long, and has three cup leathers. The bottom valve can be drawn up by means of a bell screw. The entire fittings are of gun-metal.

Fig. 8 illustrates a design of pump for deep tube wells. The working barrel is of cast iron, with a gun-metal liner. The bottom valve fits in a reducing neck to the suction, and has a taper or bell screw to facilitate its withdrawal. Both this and the bucket are of gun-metal, and of double beat type, and the latter has gun-metal spring rings alternatively with cup leathers. They are made from $5\frac{3}{4}$ in.

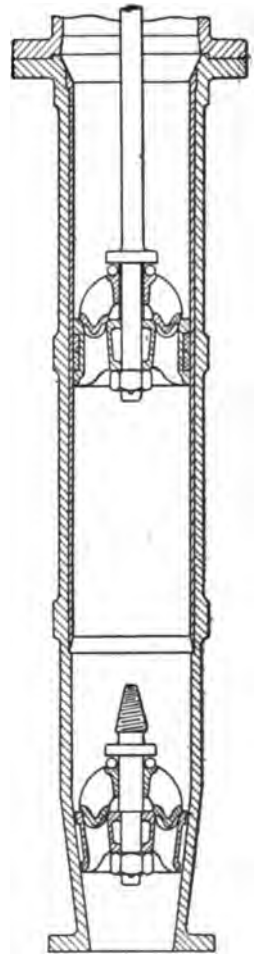


Fig. 8. — Barrel and Valves for large Pumps for deep Tube Wells. (Hayward Tyler & Co., Ltd.)

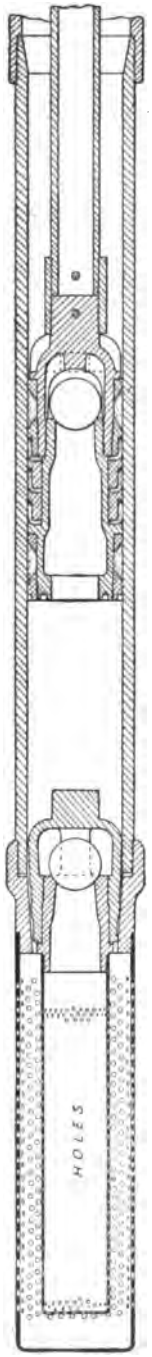


Fig. 9.—Barrel and Valve for Oil Wells.

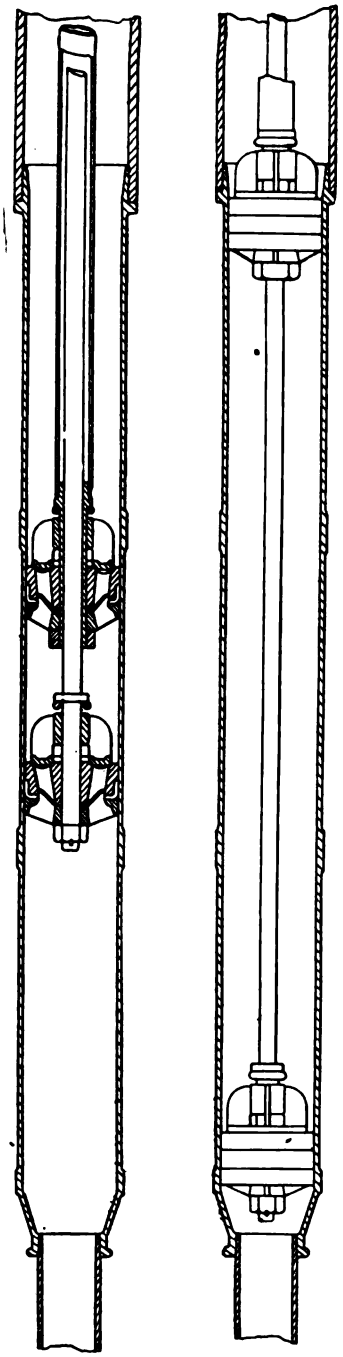


Fig. 10.—Double-action Barrel. (Hayward Tyler & Co., Ltd.)

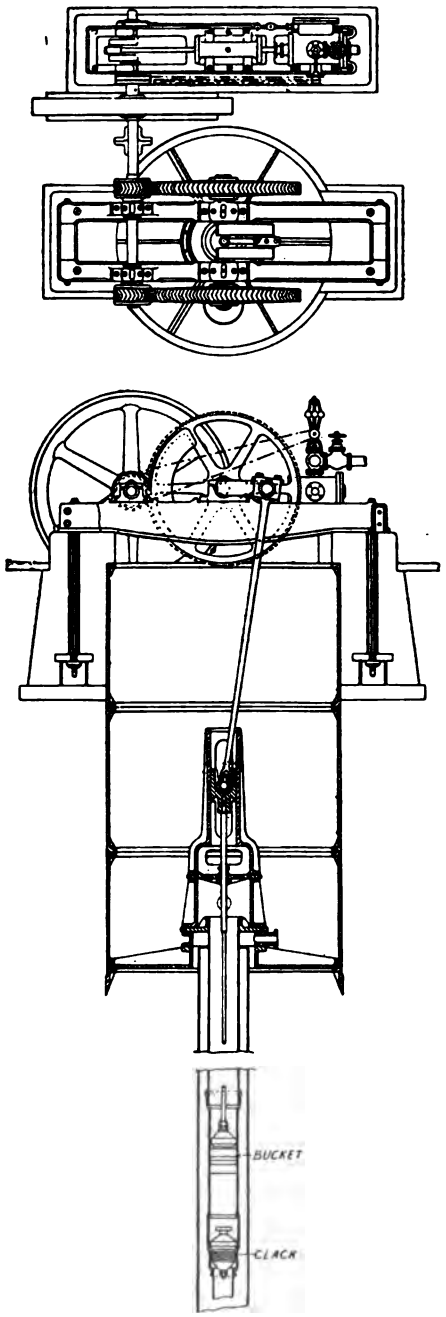


Fig. 11.—11-inch Single-acting Bore Hole Pump. (Mather & Platt, Ltd.)

to 11½ in. bore, and from 12 in. to 42 in. stroke.

Fig. 9 illustrates a working barrel of steel for unusually high lifts, with ball valves, three cup leathers, a double strainer, and a patent packing.

Fig. 10 shows a double-action pump, in which there is no fixed clack or suction valve, but two buckets worked in opposite directions by cranks. The rod of the lower valve passes through that of the upper one.

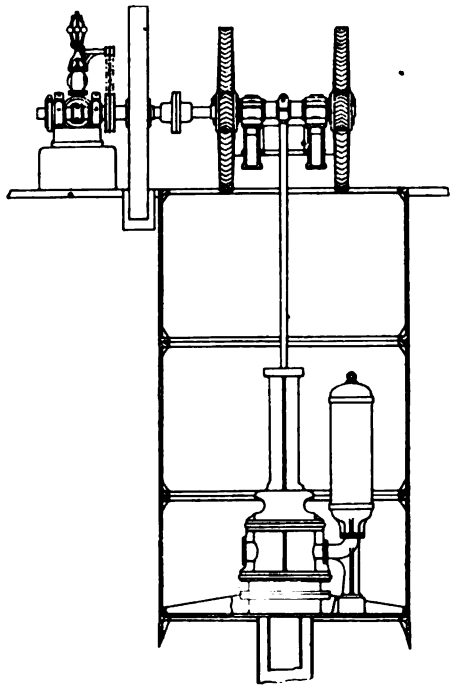


Fig. 12.—11-inch Bore Hole Pump. (Mather & Platt.) Section through cast-iron well, showing air vessel.

The Figs. 11-13 illustrate an 11-inch single-acting lift pump of 3-feet stroke capable of delivering 10,000 gallons of water per hour to a height of about 16 ft. above the surface. It is driven by a 10 in. by 16 in. horizontal engine. The steam pressure is 140 lb. per square inch, and the revolutions 80 per minute. Fig. 11 shows the main, broken off to give enlarged sections through the upper well, and working barrel. Fig. 12 is a transverse section through the upper well, and Fig. 13 is a reduced section of the entire well and its tubes and pipes. The details are so full that they hardly call for comment. The well cylinders with the bottom cutting edge will be noted. The working barrel is of brass, the bucket speed 100 ft. per minute. The suction pipe is 8 in. diameter, the delivery pipe or rising main 12 in. The pump rods are uniformly 1½ in. diameter, the lining tubes uniformly 20 in. diameter.

Fig. 14 illustrates a 9-inch combined lift and force pump, and Fig. 15 is a section through the bore hole. In the latter the scale for depth is half that for diameter. The pump delivers 110 gallons of water per minute to a height of about 25 ft. above the surface. The suction pipe is 7 in. in diameter, the delivery 10 in., and the lining tubes 15 in.

Bore Holes.—The tools with which a well must be bored vary with the nature of the strata to be pierced. The lining of the bore-hole must also be arranged to suit the particular conditions met with in any special case.

Speaking generally, wells bored in any particular stratum and into any other strata will be bored by similar tools and in some particular sequence. But when starting in a different stratum and finishing in different strata the method of procedure may be entirely changed. Probably no stratum in Great Britain has been bored into more frequently than the Chalk, and a detailed description of the method of procedure to be followed when boring a well in London, and of the tools to be employed, will enable a good idea to be obtained of the practical work of the well-borer in Great Britain.

Taking then the case of a well in the London Clay area, the following sequence of strata will be encountered. First there is a layer of gravel more or less loose, and water bearing, and varying from 20 to 30 feet in thickness. The London Clay comes next, and has a thickness of 50 to 180 feet. Following the London Clay is a long series of alternations of sands, clays, and pebbles, known as the Woolwich and Reading Beds, varying from 50 to 90 feet, and followed by the Thanet Sand, a fine-grained, often loamy sand, ranging to 50 feet in thickness, between which and the chalk there is a layer of green-coated flints about 6 inches thick. The chalk thence extends about 650 feet, its upper parts exhibiting stratified layers of black flints ranging from a foot or two

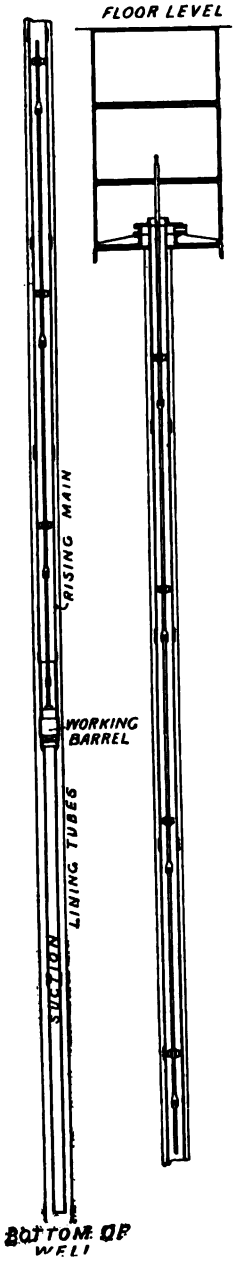


Fig. 13.—Reduced Section of Well, Tubes, and Pipes.

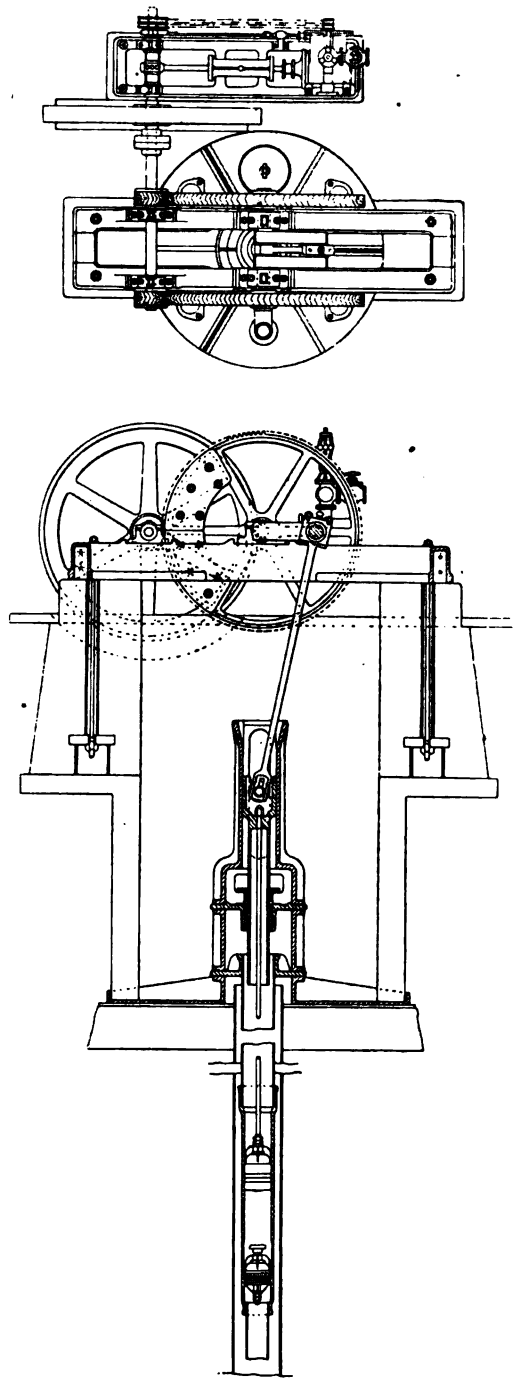


Fig. 14.—9-inch Single-acting Lift and Force Bore Hole Pump. (Mather & Platt, Ltd.)

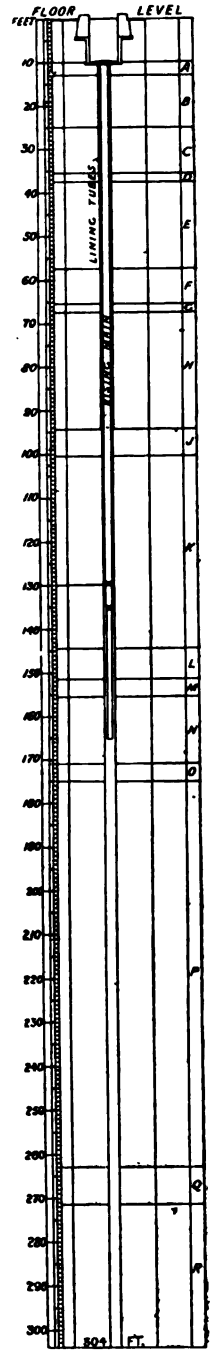


Fig. 15.—Section through Bore Hole.

REFERENCES TO STRATA (FIG. 15) IN DESCENDING ORDER.

A. Clay and gravel. *B.* Sand and gravel with boulders. *C.* Red quicksand. *D.* Gravel. *E.* Boulder clay. *F.* Dark blue clay with small boulders. *G.* Black earth with little coal. *H.* Blue soapy shales with iron-stone bands. *J.* Brown rock. *K.* Blue shale; and lower, blue shale darker, rather sticky. *L.* Grey sandstone. *M.* Brown rock. *N.* Blue shale. *O.* Black shale; and lower, grey sandstone. *P.* Blue shale, rather sticky; below blue shale, very sticky. *Q.* Grey sandstone. *R.* Blue shale with thin seams of grey sandstone; and below, blue shale, and grey sandstone (mixed).

to 10 or 20 feet apart. In the table below will be found the sections of characteristic London Borings, with the thicknesses of the main divisions.

Stratum.	Bank of England.	Mew's Brewery.	Bermondsey, Staple Street.	Streatham Common.	Barnet.
	Feet.	Feet.	Feet.	Feet.	Feet.
Made Ground	22	...	3	...	1¼
Gravel, &c. -	4	22½	23½	10	2
London Clay	111	63½	38½	153	113¾
Woolwich and Reading	58½	51½	48	43½	50
Thanet Sand -	39	21	39	35	0
Chalk - -	100	655½	95¼	558	293½
Upper Greensand - -	...	28	...	28½	...
Gault - -	...	160	...	188½	...
Lower Greensand - -	...	...	...	...	...
Jurassic -	...	64	...	38½	...
Upper Devonian -	...	...	...	?	...

The first step to be taken is the digging of a pit from 4 to 10 feet in depth. This is covered by a stout-boarded frame of timber, through the middle of which is a rectangular opening larger than the largest lining pipe that will be used, and closed by a removable *auger board*. This board is usually a block of English elm, measuring 22 × 12 × 4 in., slotted from one side to a central hole about 2½ in. diameter, and strengthened by angle-iron bars bent round the hole. *See* Figs. 16-21 for this and other tools and appliances. The auger board has to carry the whole of the weight of the tools and boring rods when suspended on the *dogs*. On the timber framing of the cover are placed the two front legs of a small derrick when hand work is contemplated. This is of iron tubes 1½ to 3 inches diameter, and 12 to 20 feet high, with a rope pulley at the apex, and a geared windlass fixed to the front legs. For steam winch work the derrick is made of 12 × 6 in. timbers, and the steam winch is a double cylinder ship winch with 5, 6, 7, or 8-in. cylinders, double-geared, and with link reversing motion. The rope wheel is about 27 feet above ground.

Lining tubes are of the following sizes:—3, 4, 5, 6, 7¼, 8½, 10, 11½, 13, 14½, 16, 18, 20, 22, 24 inches and more in diameter. Assuming that a 10-inch hole is to be bored into the chalk, a customary starting size will be a piece of 13-inch pipe sufficiently long to extend from the bottom of the dug pit into the London Clay. This piece of lining pipe extends a few feet into the clay, and effectually shuts off the gravel water or surface water from the boring beneath. Special care is taken to put this pipe truly vertical. These lining pipes are cut off exactly square by the longitudinal axis of their screwed ends, so that their exact vertical position is shown by laying a spirit level upon the top of

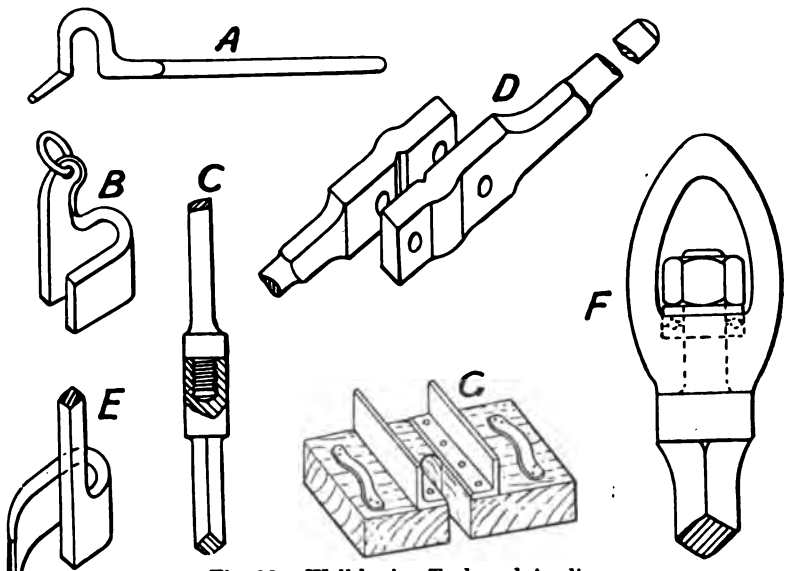


Fig. 16.—Well-boring Tools and Appliances.

A. Hand Dog. *B*. Lifting Dog. *C*. Rod end. *D*. Rod Tiller. *E*. Left-hand Crow's Foot. *F*. Swivelrod. *G*. Auger Board.

the upright pipe during the course of driving it down. It is driven into the London Clay by means of a heavy falling *monkey*, Fig. 17, with a $2\frac{7}{8}$-inch tail which enters the 3-inch hole through the centre of the *steel driving cap* which screws down solidly upon the top of the pipe. The pipe is armed with a leading *shoe* of steel and is driven hard into the gravel through a 16-inch square hole left in the concreted bottom of the pit. When driven sufficiently solid, the interior gravel is loosened with a *diamond-pointed chisel* and scooped up with a *clay auger*, Fig. 18, the mouth of which has, for loose gravel, to be closed by a thin plate guard temporarily bolted in. Clay put

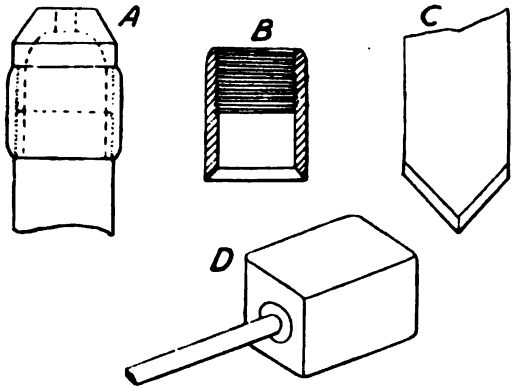


Fig. 17.—Well-boring Tools and Appliances.
A. Coupling. *B*. Pipe Shoe. *C*. Diamond-pointed Chisel. *D*. Monkey.

down and mixed up with the gravel will help in removing it, and if fine and well chiselled up with clay, it can even be removed by the shell pump, though gravel alone is usually too solid to enter a shell. The removal of gravel ahead of the shoe of the pipe permits further driving of the pipe until the clay is reached. The pipe is preserved upright by strutting it in any desired direction or wedging it as it is driven down. When it enters the clay, it is driven into this until the pipe top projects as little as desired above the pit bottom. The 13-inch pipe is then a guide for further operations. The clay is removed by the clay auger until perhaps a water pocket is met with, and the bore-hole begins to fall in, the clay being wet and rotten. The next smaller size of pipe is then inserted, *i.e.* $11\frac{1}{2}$ inches, and is progressively driven down as the clay is augered out. This second pipe may extend as far as needed. If possible it should not enter the Thanet Sand. The permanent 10-inch lining pipes will then be ready at hand, and be inserted within the $11\frac{1}{2}$-inch, and the Thanet Sand will be drilled through with the utmost possible despatch, and the 10-inch pipes as rapidly driven down to prevent the hole from falling in. When the chalk is reached, the pipes will be driven hard into it, and the hole be bored only 1 or 2 feet deeper than the pipe shoe before again driving the pipes hard. The steel shoe thus cuts its own way into the chalk.

If the hole were bored ahead of the pipes several feet, the tools might wander and make a slightly larger hole, in which the pipes would be too easy a fit. To avoid this, and because the top of the chalk is often rotten and fissured, the pipes are driven as stated above, 15 to 20 feet below the green flint layer. The standard length of an artesian driving pipe is 10 feet, but lengths of 3, 4, 5, and 6 feet, &c., are used to make up with, and a couple of short lengths are usually placed above the 10-inch shoe, so that the joint sockets may help to fix the pipe firmly. By driving 15 to 20 feet into the top chalk, it is usually certain that the lining of the well has gone beyond any fissures that might serve to admit the Thanet Sand into the bore-hole to choke it, or perhaps injure the pumps.

When the water level is lower than the above practice would place the end of the lining tube, some engineers prefer to drive the pipes deeper so that the rise and fall, when pumped, of the top level of water in the bore-hole, shall not wash the bare bore-hole, but shall occur in the lining pipe.

The lining pipe fixed, the bore-hole is then carried down to 300, 400, or 450 feet according to circumstances. Sometimes the $11\frac{1}{2}$-inch pipe is left in. Sometimes it will not withdraw, but if wanted out, it will usually come up under the pull of a hydraulic or screw-jack, and the annular space left by its removal should at once be filled by pouring down a thin wash of clay made by rubbing some of the bored-out clay through a sieve with water. With this in view, the clay as it is got should be kept in a tank with water so as to soften it ready for this

purpose. Clay should also be put down the bore-hole when cutting through flints, so as to mix the flint chippings into a soft yielding mush. Clean flint chippings or clean sand will hold fast any circular tool such as a shell or a trepan cutter, and may entail weeks of labour to remove. Hence the use of clay to prevent consolidation of the chippings.

In boring chalk or sand rock, or conglomerate, &c., there are three usual tools—the *flat chisel*, the *circular chisel*, and the *Tee chisel*.

The flat chisel is a flat parallel bar of steel or of steel-edged iron, the width of the diameter to be bored. It is forged down at the top end to a square shape, with a circular collar or boss and a short Whitworth threaded screw to take the boring rod socket.

The circular chisel is simply a length or lengths of lining pipe from 6 to 60 feet long, with a forked hanger screwed on the top end and a steel shoe at the base cut into teeth, saw fashion, or alternate numbers of saw teeth and chisel-edge teeth to keep the bore truly circular.

The Tee chisel is a flat tool with a sidepiece a few inches above the point, curved to the radius of the hole. The lower edge of this side pad is chisel-edged, and as the boring rods are slowly revolved when working, this pad ensures the cutting of a fully circular hole. The plain flat chisel is made to produce a fully circular hole by slowly raising it with every few inches cut, and rotating it rapidly. It would not rotate in a hole at all flat in cross section. Without this precaution a simple flat chisel, especially in soft rock, like chalk, will often advance rapidly, and cut a hole flat in cross section as a long pitched spiral. The pad on the Tee chisel prevents this. The circular chisel will cut cores little inferior to the diamond drill, but like all circular tools, is very liable to become stuck fast in a hole. To minimise the risk of this, no tool should ever remain half a second at rest at the bottom of a hole, or grit may at once settle round and lock it fast. It must always be kept on the move, and when work is stopped it should be hung at least 8 or 10 feet above the bottom, supported by the *dog* on the *auger board*.

The *rods* by which these various tools are worked are to be made of $2\frac{1}{2}$, 2, $1\frac{1}{2}$, $1\frac{1}{4}$, or 1 inch square best quality of wrought iron or mild steel, with circular ends, and Whitworth male and female screwed ends. The female end or socket is to be made by welding a collar round the rod end with the rolled fibre laid circularly. If these socket ends are made of bars only, they will split lengthwise when at work. The exterior of a socket if etched with acid should show whether it has been circular-welded or drilled out of a solid bar, by the development of seams or fibre. For a 10-inch hole, perhaps five 10-ft. lengths of 2-in. rod come next the tool, followed by ten or fifteen lengths of $1\frac{1}{2}$-in.

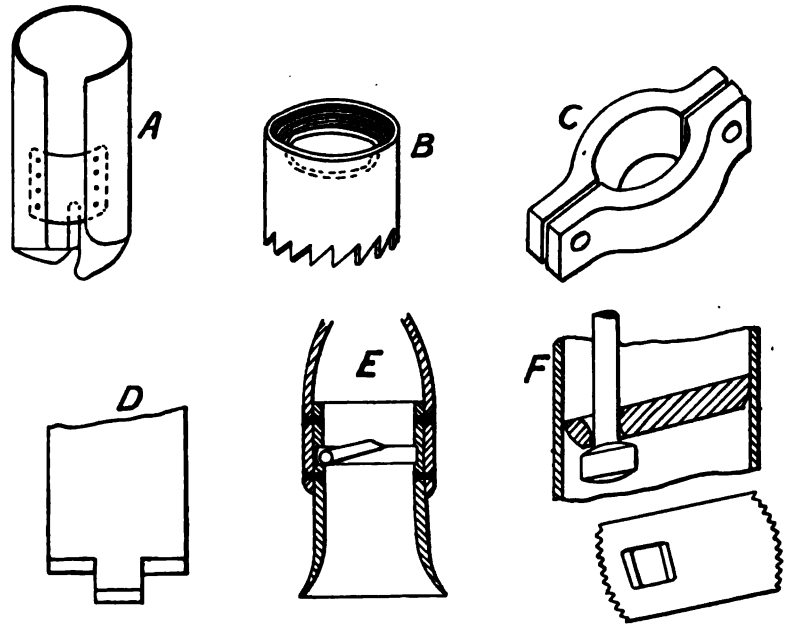


Fig. 18.—Well-boring Tools and Appliances.

A. Lower end of Clay Auger. *B.* Circular Chisel. *C.* Light Pipe Clamps. *D.* Form of large Chisel. *E.* Bell Box. *F.* Pipe Latch.

rod, and the remainder will be 1¼-in. rod. *Reducing rods* to connect rods of different size are made in lengths of 18 and 24 in., 3 ft., 5 ft., and 10 ft. On the top of a line of rods is a *swivel rod* to hang by, the swivel being fitted with a ring of balls for easy working. A spring safety hook carries the rods, and is hung by a wire rope over the derrick pulley. The rods are lifted and dropped suddenly to strike a blow by means of a rope of hemp attached to the wire rope by a suitable hitch, and carried round the winch barrel two or three times. By pulling on the end of the hemp rope with the winch running, the rope will grip the barrel and lift the rods, and will as quickly drop them when the pull on the rope is relaxed. The operation is termed *punching*. In American oil drilling, this operation is performed by attaching the top of the boring rods to an oscillating beam which is kept in motion by an engine, and there is a separate barrel for winding up and down when removing the tools. In Canadian practice, long wooden rods are used. Wire ropes are also employed both at home and abroad, and there are only some 50 feet of tools and rod in the bore-hole. A hole is less easy to bore straight and true with the rope, because the tool is apt to rotate unevenly, and is liable to go astray more readily than when controlled by rods.

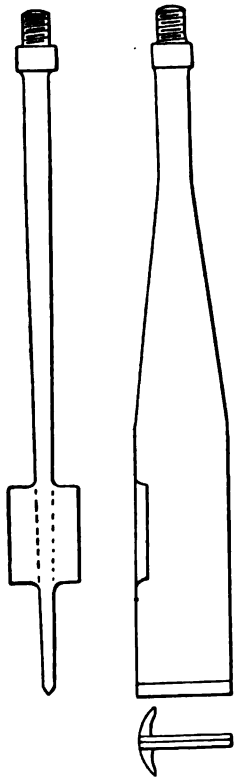


Fig. 19.—Tee Chisel.

Rods are screwed together by the *hand dog*, and when boring is in operation, are held by the workman by means of the *rod tillers* clipped by eye-bolts upon the rods.

When rods break down the hole, they are recovered by means of the *crow's foot*, which is rotated in the hole at the end of a line of rods until it catches under the rod bosses. A *latch tool* is also used to pick up broken rods, and a *pipe latch* is employed to lift pipes should these come apart down a bore-hole. Rods are sometimes made with left-handed screws for the purpose of unscrewing ordinary rods, &c., piecemeal, in case of tools sticking fast, &c., or rods are prevented from unscrewing by the clamp with manganese steel bolts; the clamp spans over the rod ends and holds on the square rod. Screw-jacks with hollow centre are used to pull on stuck-fast tools or to extract pipes, the jack being put over the pipe, and a bolted clamp put round the pipe. The head of the jack has a double ring of balls for easy rotation. The author has made such jacks with hollow malleable iron screws, a gun-metal screwed sleeve in which the screw works, and a cast-iron outer casing. Space does not permit of a description of the innumerable tools for recovering broken rods or tools. Each breakage may entail some special tool. Thus pipes are cut off at any depth below the surface by means of a pipe tool fitted with four ordinary disc pipe cutters rotated inside the pipe, the cutters being carried on spring strips forced outwards as the cut deepens, by means of a taper centre rod slowly fed downwards, the whole work of rotation and cut feeding being done from the surface. The pipe casing of this tool and the centre feed rod are made up of any convenient lengths of ordinary pipe or rod.

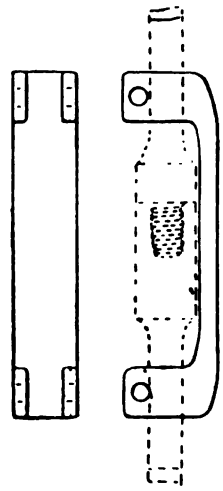


Fig. 20.—Rod Clips for Breakdown Work.

Artesian lining tubes are specially made of stout mild steel set in at each end to a diameter ⅛ inch less than the rest of the pipe, and screwed at each end exactly half the length of the socket with a Whitworth thread of 12 per inch. The pipes are cut off in the lathe to exact lengths, and they *butt* together in the

sockets. These are of special steel, thinner than ordinary sockets, and tapered down each end to a thin edge, so that they screw tightly home to the end of the last thread on the pipe ends just when the pipes butt hard together in the middle of the sockets. No driving stress comes upon the socket, but it is all taken up on the abutted pipe ends. As each fresh length of pipe is added it is screwed home to abut with certainty, and given a final wrench up after a blow has been dealt by the driving monkey.

In the operation of inserting pipes, the tier of those already inserted rests upon the pit framing by clamps which hold the pipe near its upper end, the screwed portion projecting well clear of the clamp. A fresh length of pipe is then picked up by the winch and suspended vertically above the clamped pipe. It is lowered carefully upon this with socketed end downward, and slowly turned until the socket has engaged properly with the threads of the clamped pipe. The suspending hook is then removed and the pipe screwed home. To enable a pipe to be picked up and hung vertically, a *pipe-hanger*, Fig. 21, is employed. This consists of a stout collar screwed at its lower part to fit the pipe, and plain above. To the plain part is securely riveted a stout loop of iron. Pipe-hangers are sometimes made from the sockets of pipes, but these are hardly heavy enough for constant use, for it is very important that a pipe-hanger should be a good close fit on the pipe, since too slack a thread is apt to let go under a heavy stress. The ordinary well-boring tools as sold by many makers or merchants are wholly insufficient, and most poorly and shabbily made. The chisels have no parallel length, but taper up all the way from the cutting edge. The cutting edge has the merest strip of steel in its composition. Pipe and rod tillers are fitted with nutted bolts instead of with the stout eye-bolt screws proper. Pipe clamps are narrow and light in section, and useless for anything but the smallest work, and there is indeed no single item in a whole set of tools that any self-respecting well-borer would make for himself.

The removal of debris and chips during the process of boring is accomplished by means of the shell. This is a steel pipe; the author has generally made them of ¼-inch thick pipe with a steel shoe. A leather-jointed clack valve is nipped between the shoe and the pipe end, and opens upwards. The shell is attached by a *forked hanger* to the boring rods, and dropped carefully a few inches upon the debris at the bottom of the hole. The wet debris enters the valve, which retains it, and the shell when full is raised and emptied. Being a circular tool fitting closely in the bore-hole, the shell must be used with caution, and promptly raised after each stroke, so as not to permit of debris settling round it, and fixing it in the hole.

When the circular chisel is employed to cut cores, the cores are lifted by means of a flat

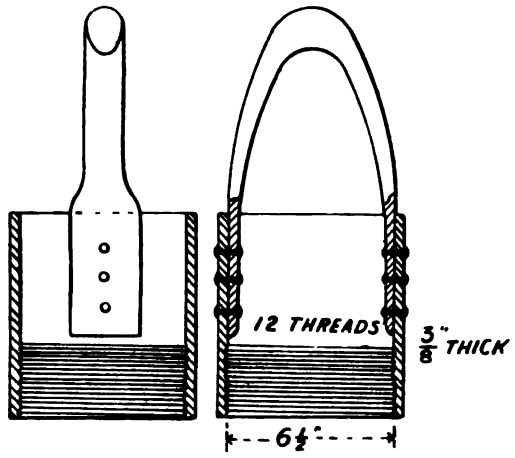


Fig. 21.—Pipe-hanger.

ring inserted in the shell in place of the valve. The ring is large enough to slip over the core, except that it has two or three small curved projections from its inner edge which will not permit the ring to be pushed over the piece of core except by the use of force. This force is given by the weight of the rods, accentuated by a slight drop of a few inches. The projections of the ring are thus compelled to pass upon the core, and they hold it sufficiently firmly to lift it. Being thin, they will bend if they cannot cut a shallow groove down the surface of the core.

The extremely variable strata met with in Great Britain are not favourable to diamond boring. The diamond drill is like the circular

tool already described, but in place of the serrated crown a plain flat-ended crown is drilled with a few small holes, and these are fitted with diamonds, the soft iron of the crown being carefully hammered or pinched around the diamonds. A 4-inch crown will contain six or eight diamonds, and may cost £90. As much as £3,000 has been paid for the diamonds in a large crown of 18 inches diameter. The diamonds are of the black variety, the best being the Brazilian Carbonados. The crown is attached to hollow pipe rods which are set in rapid rotation, a copious stream of water pumped down inside the rods serving to wash all debris up the space between rod and casing. The core stands up inside the lower part of the pipes until it breaks off, when the rods must be lifted and the core removed. It is necessary for diamond work to have an ample supply of water, and the diamond drill works best in continuous solid homogeneous rock, and seems able to cut the hardest rock with the very slightest wear of the carbonados.

A variety of the revolving drill is the Calyx. In this drill a toothed steel crown is revolved at the end of a hollow pipe rod exactly as in diamond drilling, except that the drill takes up a sort of jumping or chattering movement, and chips away the rock with considerable rapidity. Chilled iron shot is also used to drill rocks, being rolled under the end of a steel crown at the end of a line of hollow rods, and cutting into the rock by the crushing effect of the hard balls. In all this rotary work a supply of water must be kept flowing to wash away debris.

In the table given below will be found the dimensions of the various sizes of artesian well tubes and small driven well tubes, showing the length and diameter of sockets, the inside diameter and thickness of steel shoes, which have of course to pass over the outside diameter of the sockets of the pipe next smaller in size.

These dimensions are adopted by the best makers, and though not perhaps perfect, are very satisfactory generally. Obviously since the various tools and pipes must all pass down pipes of the next larger diameter, all tool diameters are fixed by the standard pipe sizes. A set of standard gauges 2 feet long should be kept in the workshop, representing the diameter of the steel shoes inside, and every tool made for work or wreck-recovering should be passed through its respective gauge before sending it out or passing into stock. Borings are rarely made under 3 inches diameter, but it may happen that owing to unforeseen circumstances greater depths have to be reached than anticipated, and pipes become fixed, and necessitate more frequent insertion of smaller pipes. The writer has been compelled to resort to the use of $1\frac{1}{4}$-in. lining pipes at a depth of 1,200 feet, using a specially turned pipe tool to penetrate the last few feet of hard Gault clay at a depth of 1,234 feet. When water was struck finally it was only when cores as small as wine corks were being extracted.

Nominal Diameter.	1¼ in.	2 in.	3 in.	4 in.	5 in.	6 in.	7½ in.	8½ in.	10 in.	11½ in.	13 in.	14½ in.	16 in.
Diameter at Cressed Ends	...	...	$2\frac{7}{8}$	$3\frac{7}{8}$	$4\frac{7}{8}$	$5\frac{7}{8}$	$7\frac{1}{8}$	$8\frac{3}{8}$	$9\frac{7}{8}$	$11\frac{1}{2}$	13	$14\frac{1}{2}$	16
Diameter outside Body	$1\frac{5}{8}$	$2\frac{1}{2}$	$3\frac{1}{2}$	$4\frac{1}{2}$	$5\frac{1}{2}$	$6\frac{1}{2}$	$7\frac{1}{2}$	$9\frac{1}{2}$	$10\frac{1}{2}$	$12\frac{1}{4}$	$13\frac{3}{4}$	$15\frac{1}{4}$	$16\frac{3}{4}$
Length of Steel Sockets	$2\frac{1}{2}$	3	4	5	5	5	6	6	8	8	9	10	10
External Diameter of Sockets	$1\frac{5}{16}$	$2\frac{1}{16}$	$3\frac{3}{4}$	$4\frac{3}{4}$	$5\frac{3}{4}$	$6\frac{7}{8}$	$8\frac{1}{8}$	$9\frac{7}{16}$	$10\frac{1}{16}$	$12\frac{3}{16}$	$14\frac{5}{16}$	$15\frac{3}{16}$	$17\frac{5}{16}$
Thickness of Pipe	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$
Weight of 10 ft. of Pipe, lb.	17	$29\frac{1}{2}$	95	108	144	230	280	336	387	492	627	705	774
	(5 ft. lengths)												
Length of Cressed End	...	...	5	$5\frac{1}{2}$	$5\frac{1}{2}$	$5\frac{1}{2}$	6	6	7	7	$7\frac{1}{2}$	8	8
Inside Diameter of Steel Shoes	...	$1\frac{1}{16}$	$2\frac{1}{16}$	$3\frac{1}{16}$	$4\frac{1}{16}$	$6\frac{1}{16}$	$7\frac{1}{16}$	$8\frac{1}{16}$	$9\frac{1}{16}$	$11\frac{1}{16}$	$12\frac{3}{16}$	$14\frac{1}{16}$	$16\frac{3}{16}$
Thickness of Steel Shoes	...	$\frac{7}{16}$	$\frac{7}{16}$	$\frac{7}{16}$	$\frac{7}{16}$	$\frac{9}{16}$	$\frac{9}{16}$	$\frac{9}{16}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{5}{8}$
Diameter of Chisels	...	$1\frac{3}{4}$	$2\frac{3}{4}$	$3\frac{3}{4}$	$4\frac{3}{4}$	$5\frac{3}{4}$	$6\frac{7}{8}$	$8\frac{1}{8}$	$9\frac{1}{2}$	$11\frac{1}{8}$	$13\frac{5}{8}$	$14\frac{5}{8}$	$15\frac{5}{8}$
External Diameter of Steel Shoes	...	$2\frac{1}{16}$	$3\frac{1}{16}$	$4\frac{1}{16}$	$5\frac{1}{16}$	$6\frac{1}{16}$	$8\frac{3}{16}$	$9\frac{1}{2}$	$11\frac{1}{16}$	$12\frac{7}{8}$	$14\frac{7}{16}$	$15\frac{5}{16}$	$17\frac{7}{16}$

Above 10 inches diameter the ends are not reduced. It would be better to increase the thickness of the $\frac{5}{8}$-in. thick shoes to $\frac{11}{16}$ in. or $\frac{3}{4}$ in. by reducing their internal diameter.

Finally, while the foregoing gives an outline of the art of boring, the actual work differs in every instance, and only experience can decide on tools and procedure as each change or difficulty arises.

The value of bore holes for the supply of pure and cheap water is increasingly appreciated in industrial operations. They render firms independent of the more expensive towns' water, and nearly independent of fluctuations in rainfall. The plant employed includes, besides hand derricks already mentioned, power methods. The subject is too wide to be treated *in extenso*. We can only illustrate one type of machine, Fig. 22, Plate I., which is a round rope type. It consists of a timber tower, about 60 feet high, with a guide pulley at the top. On the base, at one side there is a hoisting drum with bull wheels, on the other a walking beam. The latter is actuated by a connecting rod and crank, driven by a large belt pulley from a steam engine. One end of the walking beam is connected by a round rope to a boring bar of great length and weight, the other end of the rope being coiled on the bull wheel drum, which is fitted with a brake. The crank arm has several holes for the reception of the pin, to permit of various lengths of stroke.

The boring bar hangs at distances of from 6 inches to 3 feet from the bottom of the hole. The motion derived from the walking beam causes the heavy bar to rise and fall in the hole, with a periodic motion, and the suspended weight stretches the rope until the cutters touch the bottom, when the whole rapidly rebounds. The man at the surface twists the rope, so rotating the bar, which thus penetrates the rock, and as the boring proceeds he feeds out the rope by means of a screw and nut. The boring tools are withdrawn by the bull wheel and engine. The bore hole is cleaned by a sludge pump, which is actuated by a winding drum seen to the left of the photo. It is withdrawn and emptied until the debris has been removed.

The machine used in the flat rope system occupies less space than the round rope one, and it brings up solid cores from any depth. The boring head and sludge pump are suspended in succession from a flat hemp rope, and raised and lowered by a winding drum and small engine. When the boring head is lowered to the bottom of the bore hole the rope is secured by a clamp. The boring head is lifted and released rapidly by the admission to and release of steam from the jumping cylinder, so that it strikes heavy blows in the bottom of the bore hole. It is rotated automatically by a ratchet device, which constantly twists and untwists between successive blows.

Boring.—Boring constitutes one of the largest classes of operations in the shops, both in metal and wood. In the latter material the production of holes by bits or augers is always termed boring, but in metal there is no such hard-and-fast distinction. Boring is often distinguished from drilling by the latter being done out of solid metal, but this is not by any means universally accepted. Generally speaking, however, boring may be stated as the operation of enlarging holes (already cored, forged, or rough drilled) with a boring bar or tool. Either the work, or the cutting tool may revolve, depending on convenience, and the class of machine employed.

For awkwardly shaped and massive pieces it is preferable to fix them, and revolve the cutting tool, but much light work can be attached to a rotating table, as that of a vertical boring machine, while the tool is stationary, except for the feeding movements. The principal source of trouble in boring is that due to want of sufficient rigidity in the tool or its holder, resulting in vibration, chatter marks, and holes of untrue form circularly or longitudinally. The square section tools employed in slide rests for boring are often carried out further from the rest than is consistent with rigidity, and they spring back from the work, especially at hard spots in the metal, so that the bored hole is neither circular nor parallel. When holes begin to get rather deep, say beyond 2 feet, the boring bar is preferable, being both quicker and more accurate, because of its support at two positions, and also by reason of the multiplication of the cutters (from two upwards) ensuring better balancing, and more rapid tooling.

Boring is done in the ordinary lathe with tools gripped in the slide rest, in which case

the work is revolved; or a bar may be used between centres, and the piece be fastened to the rest, and traversed by this. Alternatively the work may remain stationary, and the boring head travel along its bar, which is the plan adopted for medium and heavy jobs. Many special machines have been developed from the lathe model, having greater conveniences for rapid handling—such as rising and falling tables, upon which the work can be set for height; and a large area of table is provided with tee slots, for facility of clamping. The bar is also incorporated in the build of the machine, sliding through the head, and running saves shifting a piece, and tends to greater accuracy and alignment.

Detailed references to the various boring processes, machines, and appliances will be found under suitable headings.

Boring Bar.—This appliance is the alternative to the boring tool formed solidly with a shank and used in the lathe. The limitations of the solid type are soon reached, and support at both ends is necessary to ensure rigidity in doing long bores. This support may be either by point centres, as in the lathe, or by circumferential fitting, as in boring where the bar is incorporated in the construction.

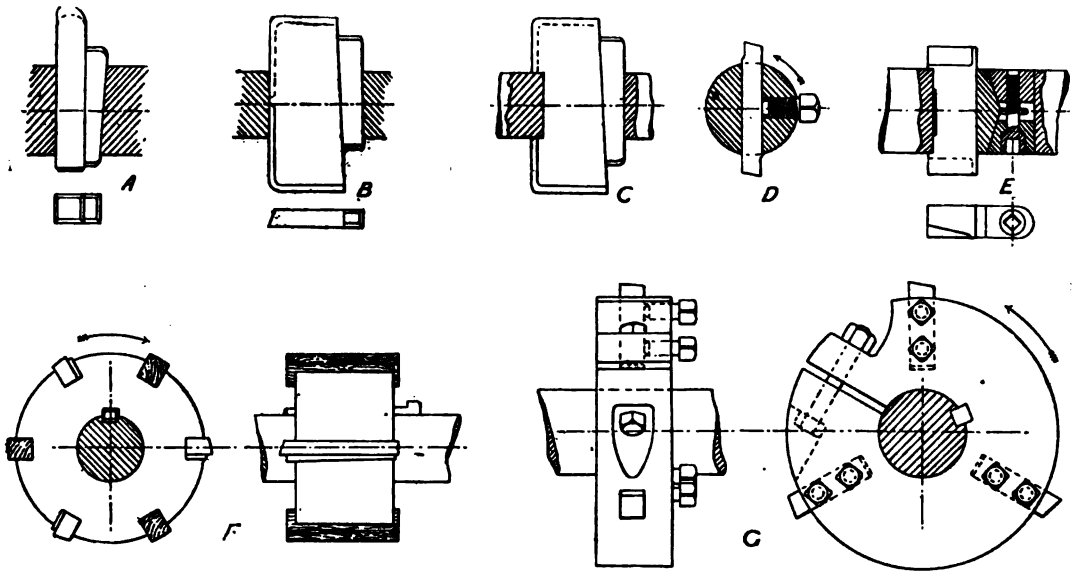


Fig. 23.—Cutters for Boring Bars.

in a bushed bearing at the free end, the equivalent of the lathe poppet. Other variations are found in the designs having a longer table without height adjustment, the bar or bars being carried in slides which rise and fall upon the faces of columns. In these and other forms the bar still affords the means of holding the cutters. But on considering another form of lathe variation, the vertical boring mill, we find that both the bar and the single tool held in a slide are employed, according to their respective suitability. Many boring machines are also adapted for milling, as well as the usual facing of flanges, &c. This is a great advantage on some classes of work, because it

The simplest form of bar is a plain round one, having centre holes in the ends, and a flat, or round cutter held with a wedge, or set-screw. Methods of fitting these are shown in Fig. 23, at A, B, C, D, and E. A is a square cutter wedged in, and having one cutting edge. This is suitable for small holes, but it is liable to bore untruly if forced, so that the double cutting types shown in succeeding figures are preferable. One distinction between the two forms is that the single cutter can be adjusted radially to bore varying sizes, but the double ones will only cut to one dimension—that is, when both edges are in operation. B and C differ, the latter being notched so that it cannot slip,

which is likely to occur in the previous types shown. The use of a screw as at D is preferable, because no hammering need be done, as with wedges. E is a wedge and screw fitting, which has the advantages of both systems combined, the act of tightening up the screw wedging the loose piece against the back of the cutter.

As holes increase in size it is no longer possible to hold the cutters direct in the bar, because of the excessive overhang. The alternative of making the bar very large is unnecessary, because a head of suitable diameter can be attached, carrying the tools out to the radius necessary, as at F. A disc is keyed on the bar, and the cutters are wedged in the slots on the periphery. This view also shows the use of side, a key D drives the head around; the sides of the nut C are flatted to slide in the screw recess, and help to drive the head. The cutters F are held in with straps, clamping the tools in grooves. The entire bar is driven around by a plate G mounted on the end, and driven from the lathe face plate by bolts. Instead of the star feed, which gives an intermittent progress to the tool head, a method of continuous feeding is preferable, being attained by differential gearing at the end of the bar; the latter is extended into a bearing neck, and beyond this a wheel is attached, the first in the differential train. The change in rate is obtained by making the wheels with unequal numbers of teeth, from one to six, so that the speed of transmission is delayed, and thus the screw is turned as the bar

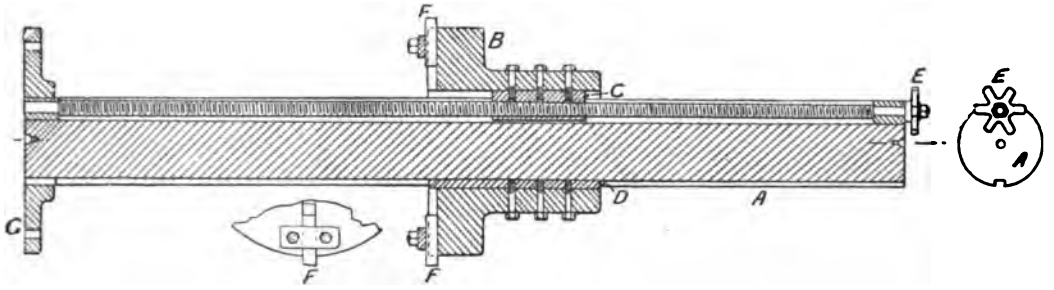


Fig. 24.—Self-acting Boring Bar.

wood slips which act as steadies in the hole, these being alternated with the cutters. A head in which set-screws are employed for pinching is shown at G; the body is split, and clamped tightly on the bar with the bolts. A key may be employed, or not.

For the larger sizes of work, the device of fixing the cutter head upon the bar is discarded, because it is undesirable, and very troublesome to move a massive piece of work along. This is obviated by causing the head to travel on the bar at a definite rate as revolution is going on. Fig. 24 shows a typical bar having this provision, and used in lathe or boring machine. The bar, A, of cast iron, has a recess running longitudinally for the reception of the feed screw. The latter is rotated by a star wheel E at the end, which strikes against a projection on the machine at each revolution, and gives the screw a partial rotation. The boring head B has a nut C held in with screws, and at the opposite revolves. The arrangements of such differential gears are varied to suit particular machines, but the effect is always the same. *See* **Differential Gears.**

For large bores of several feet in diameter the cutter head in Fig. 24 is unable to carry the tools at the requisite radius, and recourse is had to supplementary heads, which are either bolted or keyed upon the small head. These are either of spider form, having arms, at the ends of which the cutters are held, or are of disc shape, cast with lightening holes.

Portable bars, as distinct from machines, are extensively employed, both for new work, and for re-boring worn holes. An example is shown in Fig. 25, the Capitaine design. The bearings A, A, for the bar are bolted to the work, in this case a cylinder. The bar B is rotated by a worm drive at C, from a flexible shaft, or a motor. The handle D is for adjustment of the bar endwise through gears, and rack, a star feed being

also fitted as seen to the left of the gear-box. E, the cutter head, has also provision for facing, as shown by the dotted tool at the right. Angular boring is done by the upper inclined slide.

Boring Collar.—A **Cone Plate.**

Boring Head.—*See* **Boring Bar.**

Boring Lathe.—*See* **Boring Mill** and **Chucking Lathe.**

Boring Mill, or **Boring and Turning Mill.**—This is a special form of the lathe which has developed rapidly in recent years. It possesses many advantages over the ordinary type for certain classes of work, especially those having relatively large diameters in conjunction with shallowness—that is, requiring no poppet centre, for extra support. The horizontal position of the face plate is the chief advantage, facilitating chucking operations. It is easier to lay a piece on the level plate and grip it than to steady it against the vertical plate of the ordinary lathe, while clamping is being done. This is not of so much moment if simple gripping with the chuck jaws is to be done, but when packing, bolts, washers, nuts, and clamps have to be arranged, and the work adjusted tentatively, the horizontal position is greatly to be preferred. As the piece does not tend to fall away from the plate, the clamping need not be so hard, which is better from the point of prevention of distortion. Another point, not often noted, is that in heavy pieces requiring the use of the crane, the latter can be freed directly the job is lowered on to the plate, while this is impossible with the vertical plate, until secure clamping has been done. The practice of bolting down a number of awkward pieces on the plate for facing, instead of planing or milling them, is followed extensively where it would scarcely be thought of in the ordinary lathe, unless the plate of the latter were small enough to be removed for the purposes of chucking. No counterbalancing is necessary with the horizontal plate, for lop-sided pieces, as in the ordinary lathe.

Mills are made with either one or two tool-carrying slides; two in the larger sizes, so that simultaneous boring and turning operations may be performed; sometimes also a supplementary slide is attached to one upright, for turning the peripheries of large work. Three heads are also mounted on the cross rail for special work, one central boring bar, and two turning bars. The small mills frequently carry a turret, unless they are of plain boring type only. The slides have cross movements for facing, and vertical ones for boring and turning. By angling the slides bevelled faces may be bored or turned. A screw-cutting attachment is sometimes provided, and used chiefly for cutting face scrolls, as for chucks.

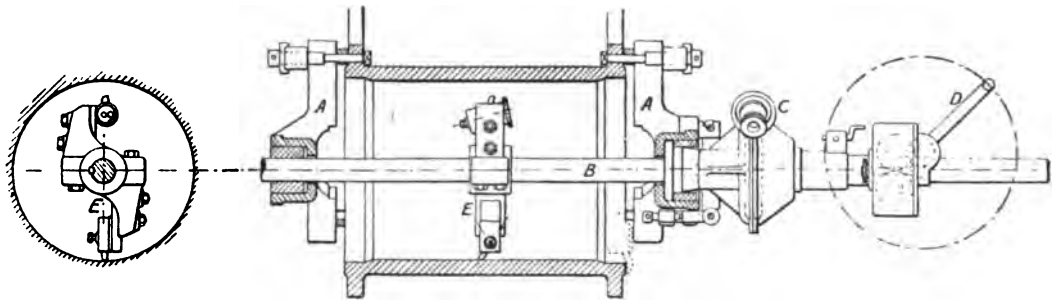


Fig. 25.—Portable Boring Bar.

The means for gripping work are very similar to those of ordinary lathes. The small mills have their tables fitted as three or four-jaw chucks. It may be necessary to supplement the gripping powers of these with bolts and clamps, tee slots being provided in the chuck face for these. The larger machines have tee slots only; face plate dogs may be utilised if suitable. Many various rigs are devised in the form of special castings to hold awkward pieces securely, frequently at definite angles. As already mentioned, the horizontal position of the table greatly facilitates the rigging up of such jigs, and irregular pieces.

The methods of carrying the tables and spindles of mills are varied, but the retention of concentricity must always be borne in mind. This is effected in some designs by a sloping bearing face, which tends to automatically centre the spindle. Fig. 26 shows the Richards method, which is based on the principle of the "Schiele" curve. The spindle is prevented from rising by the collar at the bottom. In any case the amount of bearing surface is greater than can be provided on an ordinary lathe with horizontal spindle. Heavy mills have an annular bearing ring close to the outer diameter of the face plate so that absolute rigidity is ensured, even when cutting on the largest sizes.

The device of increasing the capacity of a mill by having adjustable housings, which slide back to accommodate extra sizes of work, is in some shops a convenience when only one mill of large size can be employed, and pieces of extra diameter are occasionally tackled. *See* pp. 41, 42.

The tools used on these machines comprise the usual turning and boring types, as employed in lathe work, made from rectangular steel, and bent when necessary; various drills and boring bars, the latter having cutters pinched with screws. Reamers are also used considerably, the "floating" type being common for finishing holes already roughed out. Form turning tools, having broad edges for finishing a surface, are often employed, the rigid construction of the machines enabling heavy cuts to be taken without chatter.

A 30-inch mill by Webster & Bennett is shown in Fig. 27. The frame is a single casting, carrying the cross slide and table bearings. The table A is bolted to the spindle, and the latter runs in adjustable taper bearings, a nut at the spindle end preventing rising, should undercutting be done on work. The toothed spur ring D which is bolted to the table runs on an annular face, as seen, taking the thrust close to the outer diameter. (It may be noted that the former practice of using a bevel gear drive for the tables of mills is largely obsolete with most manufacturers, the spur ring being preferable because it has no tendency to lift the table under hard driving.)

The table has three jaws, and tee slots may also be provided. The driving is through the four-stepped cone E which derives motion from the pulley F, belted from an electric motor on the floor (not shown). E drives down to G. The latter may alternatively be belted from an overhead countershaft in the usual manner, if the motor drive is dispensed with. From G two rates are available, through gears H, J, K, L. The shaft on which G is mounted is either rotated directly by it through the clutch seen, or more slowly by sliding in K, and so driving through the four gears. Eight changes are thus obtainable, two for each of the four steps of G. The mitre gears M, N, drive the vertical spindle on the end of which pinion O rotates the spur ring D. A brake P is fitted, pressing a wood shoe against the table rim, so that it may be brought to rest quickly, resulting in a considerable saving of time.

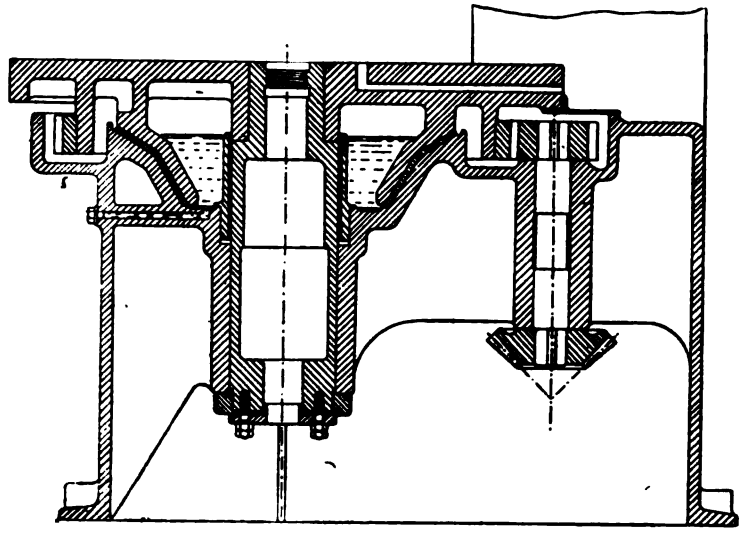


Fig. 26.—Design of Table, with Double-coned Bearing.

The slide feeds are derived from the pulley Q, driven from the shaft of M by mitres. A belt goes up to pulley R, and this, by means of

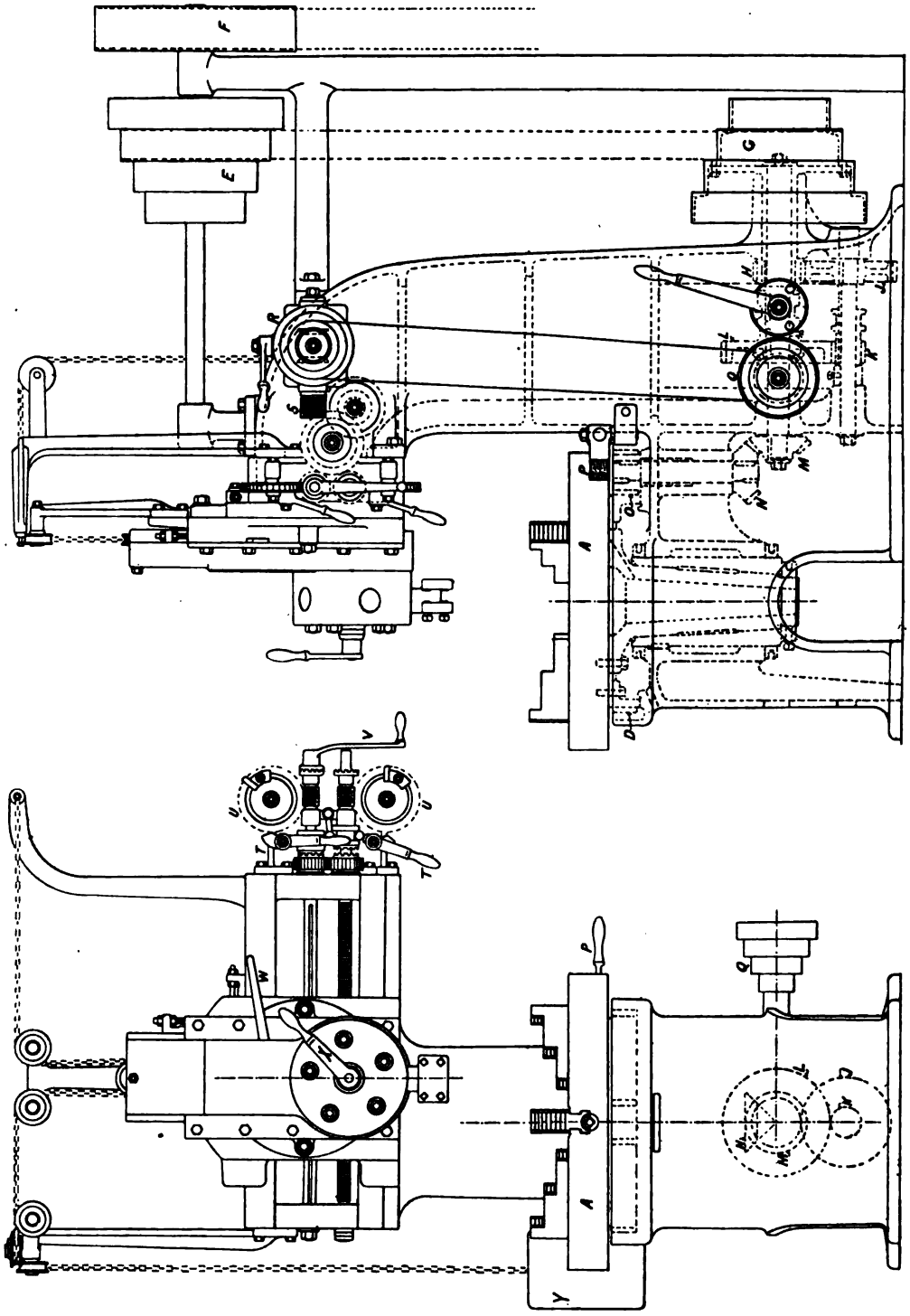


Fig. 27.—30-inch Boring Mill.

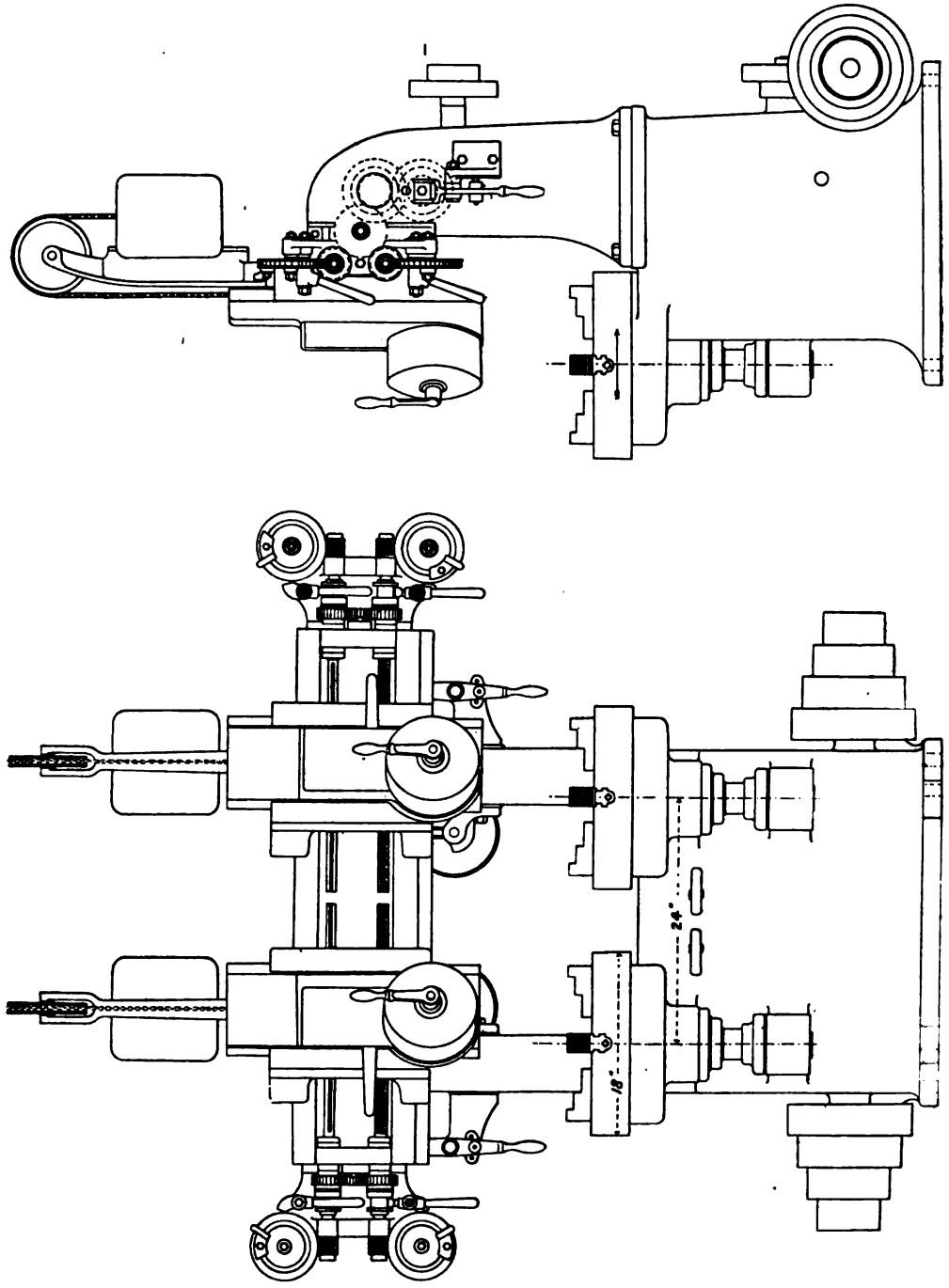


Fig. 28.—14-inch Duplex Boring Mill.

reversing bevels, drives the worm S. This actuates a train of spur gears, which rotate the screw, and the splined rod seen in the front view. The screw gives the cross traverse, and the splined rod the vertical feeds. The spurs do not drive direct on these, but through the medium of claw clutches (seen in the front view), put into mesh by the handles T, T. The tripping is performed in an ingenious manner; worm wheels U, U, are rotated slowly as the clutches revolve,

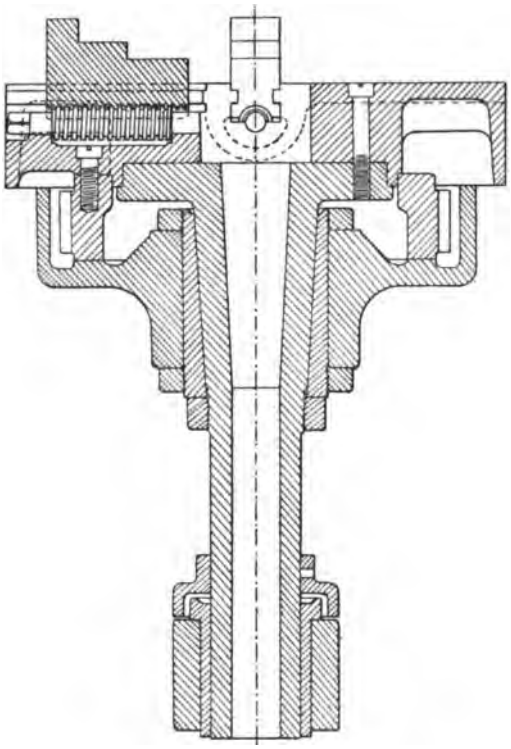


Fig. 29.—Detail of Table of 14-inch Duplex Boring Mill.

by worms on an extension sleeve of each. U, U have dogs bolted to their faces at any position of the circle, and these are set to strike the lugs on the handles T, T, and so jerk the handles out of gear. The handle V serves to adjust the slides by hand. The slide can be angled for tapered work without affecting the feeds. The turret is locked by the lever W, and clamped by X. The counterbalancing of the weight of the vertical slide is performed by the arrangement of chains suspending the weight Y.

Another variety of mill by the same firm is shown in Fig. 28, a 14-inch duplex type. This can be operated by one attendant, and occupies but little more space than the single type. Work may be bored on one table, and turned on the other, or similar operations carried on in each. It will be noticed in this case that the turrets are placed on the angle, which is done to allow long tools, as bars and reamers, to clear each other, an impossibility if the turret holes faced in line.

The table designs differ from the previous example, being of lighter type. A separate detail of one is given in Fig. 29, showing the chuck fitting, and lower bearing. Eight speeds are obtainable, through similar mechanism to that in Fig. 27. The feeding arrangements also resemble those in the previous example, but the method of balancing the slides is modified. The turrets have five holes.

A duplex 30-in. design seen in the photo., Fig. 30, Plate II., has some resemblances to the 14-in. mill. The power feeds are produced in a similar manner, and in addition a power quick return is provided to bring up or withdraw the tools quickly. The hexagon shape of the turrets allows of heavy tools being securely held, by set-screws, supplementing the large central shank hole. 24 in. in height is taken under the turrets.

Two examples of work are seen in Figs. 31 and 32, Plate II. The first illustrates simultaneous facing, and turning, a class of operation which constitutes a large amount of the work of the double slide machine; the second a deep motor-end casting, which would be difficult to hold on the ordinary lathe. Special jaws are in this case attached to the chuck jaws, standing up to hold the frame securely, while a long bar reaches down to bore the hole. Other tools in the turret subsequently turn and face the boss, and groove it.

A table of speeds and feeds compiled by the firm from data obtained on a 30-inch mill is appended. It is intended only as an approximate guide for working under average conditions.



Fig. 30.—Duplex Boring Mill. (Webster & Bennett.)



Fig. 31.—Facing and Turning Valve Flanges on Boring Mill. (Webster & Bennett.)



Fig. 32.—Boring Motor End-bearing, held in Special Chuck Jaws. (Webster & Bennett.)



Fig. 33.—Double-headed Boring Mill.

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	Cast Iron.	Steel.
Cutting speed	70 ft. per min.	80 ft. per min.
Rough turning	34·9 cuts per in.	34·9 cuts per in.
Finish turning	13·9 „ „	34·9 „ „
Broad cutting	7·76 „ „	
Rough boring, holes up to 1½ in.	62·8 „ „	62·8 „ „
Finish boring	25·12 „ „	62·8 „ „
Rough boring, holes above 1½ in.	34·9 „ „	34·9 „ „
Finish boring	19·4 „ „	34·9 „ „
Reamering	7·76 „ „	13·9 „ „

by bolts, and the driving spur ring B attached to A takes a bearing on the bed C, running on a faced ring. The difference between this and the method of carrying the vertical face plate of ordinary lathes is obvious, the latter having no support away from the spindle. C is built up in segments keyed and bolted together, as shown by the section at the extreme left, under C. The spindle D runs in two bearings, the upper one consisting of a divided socket E, adjustable by set-screws within the bed C, so that exact centring may be effected.

The lower spindle end is carried in the footstep seen, running in a cast-iron bush. This

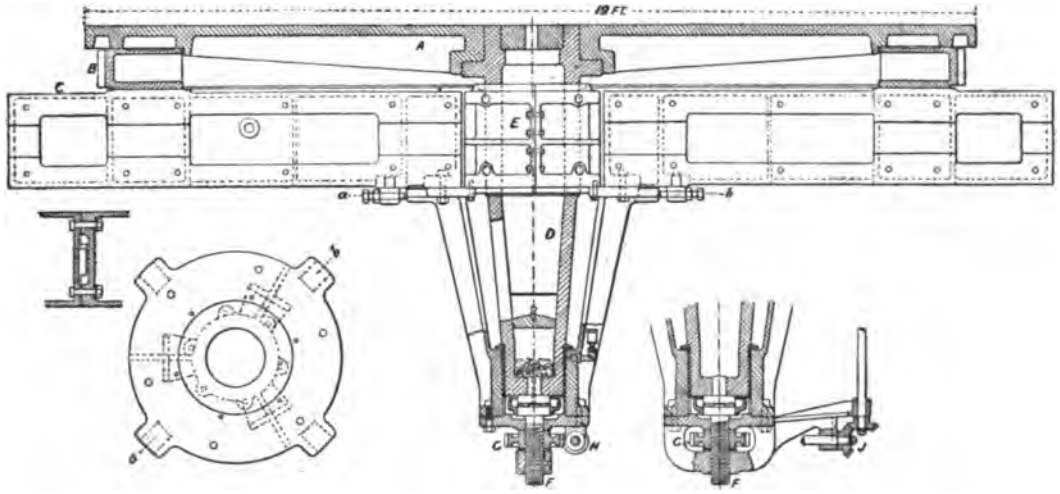


Fig. 34.—Table Fittings of 32-feet Boring Mill.

A machine by De Fries & Co. (Düsseldorf) is shown in the photo., Fig. 33, Plate II. It is of double head type, carrying two bars, which slide in the saddles, and can be angled for cone turning or boring. A range of feeds is given by the gear-box seen to the right. The heads are balanced by the ropes passing over pulleys, and having suspended weights, as seen. The hoisting of the cross slide is performed by power, through the vertical shaft, driving to bevel gears on the ends of vertical screws within the housing slots.

Details of the table and spindle fitting of a large machine, taking 32 feet in diameter, by John Hetherington & Sons, Ltd., are given in Fig. 34. The mill is shown in Fig. 35, Plate III. The table A is built up in halves, united

step embodies provision for raising the entire spindle and table, so that it may be run right off the bearing ring on the bed C—a useful feature for running the table around quickly when making adjustments of work. A square-threaded screw F, 4½ in. diameter, is prolonged as seen into shouldered form, and has a brass washer on the top, immersed in oil held by the cup seen below the end of D. A plug inserted in the latter runs on the brass washer, the weight of the table and spindle coming on this when raising is being done. The latter is effected by the worm wheel G, rotated by the worm H, which is driven by the bevel gears J seen in the right-hand view, revolved from a vertical hand wheel shaft going up above the floor level.

Fig. 36, Plate III., is a special design of mill,

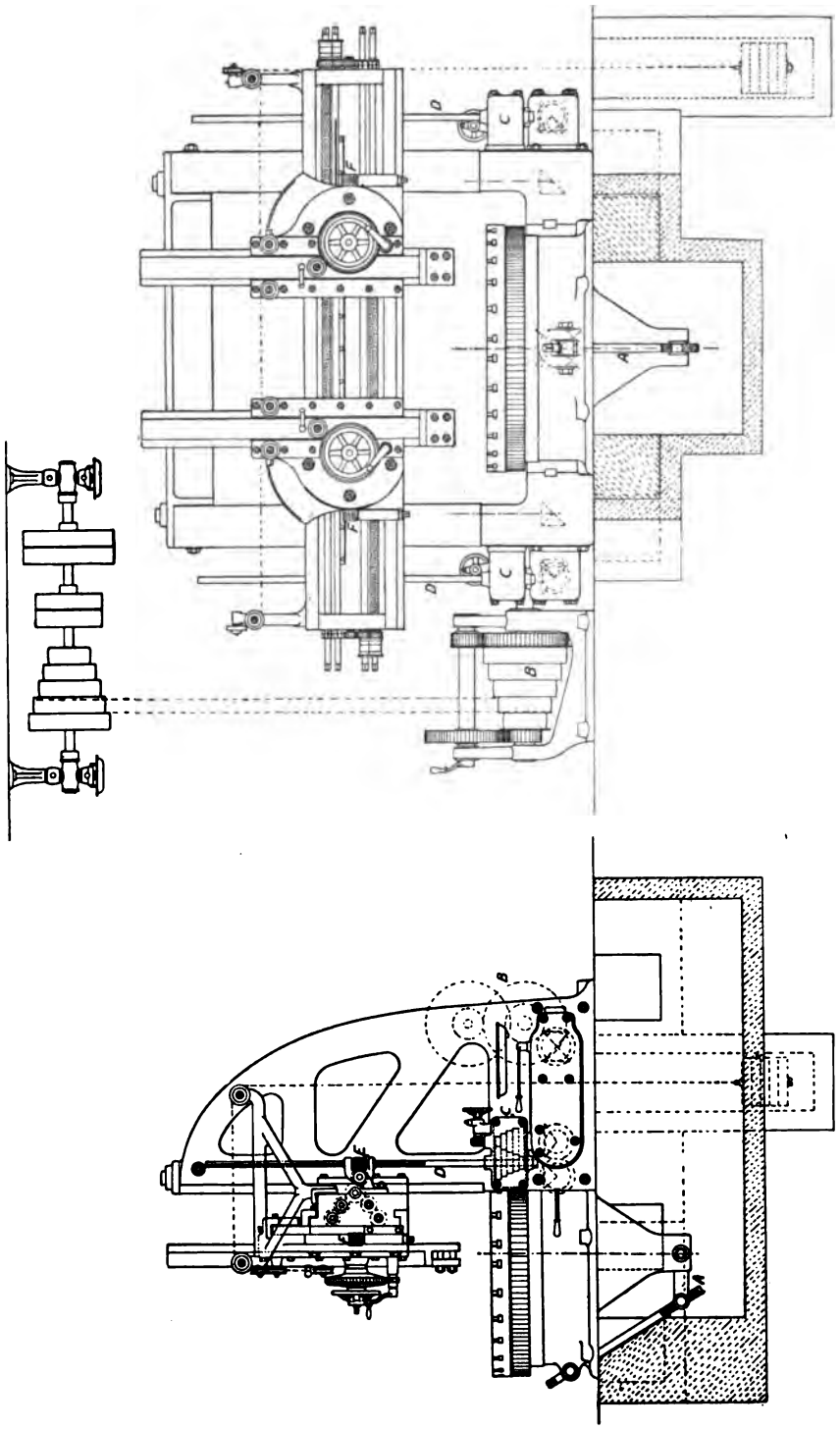


Fig. 37.—Boring and Turning Mill.

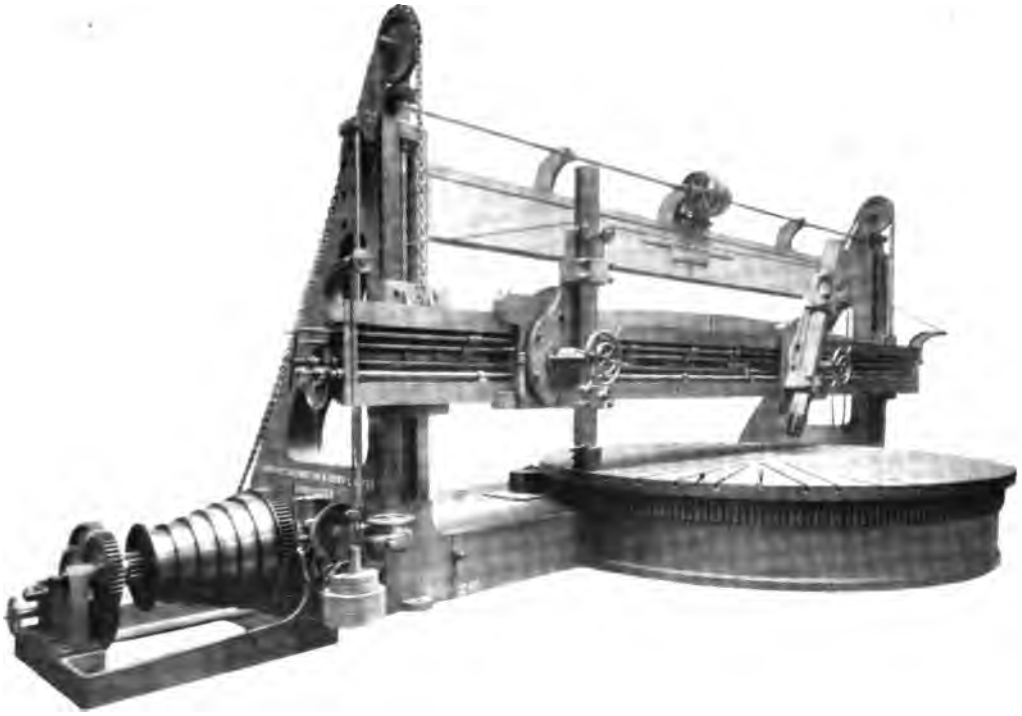


Fig. 35.—32 Ft. Boring and Turning Mill. (John Hetherington & Sons, Ltd.)

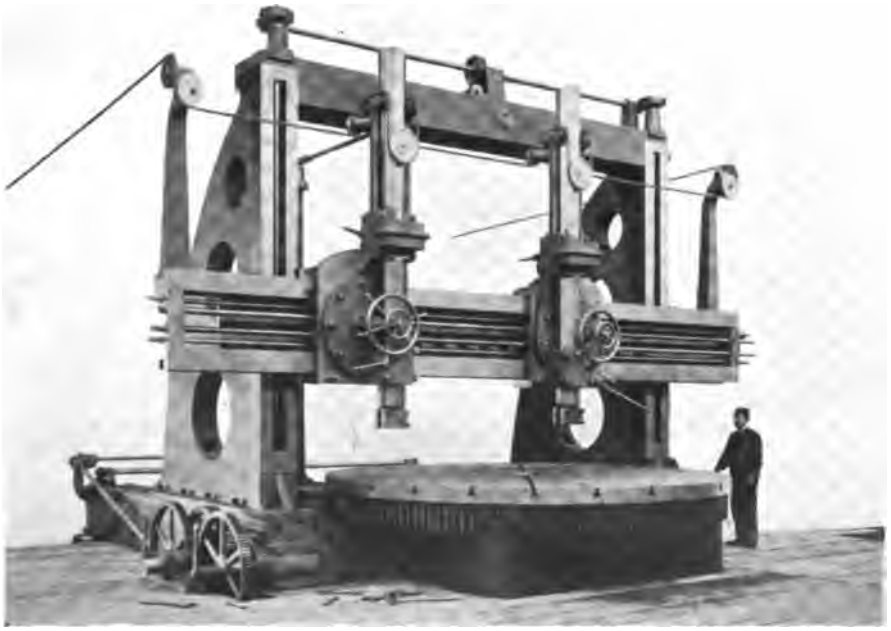


Fig. 36.—Extension Boring Mill. (Niles-Bement-Pond Tool Co.)

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in which the housings are mounted on slide ways, and can be travelled backwards, so increasing the capacity of the machine from 16 ft. to 24 ft. when required. In the latter

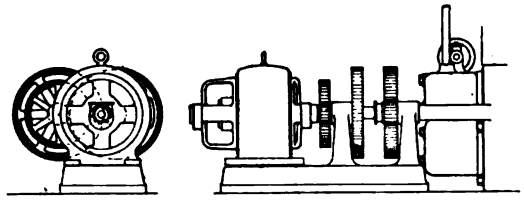


Fig. 38.—Motor Drive for Fig. 37.

case an extension boring holder may be provided, carrying the bar out over the centre of the table. The greatest height admitted under the tools is 7 ft. 6 in.

A boring and turning mill by the Société Anonyme des Etablissements Fetu-Defize is shown in Fig. 37. As in the example, Fig. 34, provision is made for raising the table, in this case by the screw A seen in front of the bed, which works a pivoted lever under the footstep. The driving may be done as shown with the five-step cone pulley B, and back gears, or by motor, see Fig. 38, and gears. The feed changes are derived from the nest of gears contained in the boxes C, C, on the sides of the housings, driving thence the vertical splined shafts D, D, at the housing sides, from which the worms E drive the train of gears connecting to the splined rods, and screws for feeding. Hand feeds are provided for these movements also. The saddles of the tool holders swivel for taper work, being moved by the worms F, F.

Boring Rest or **Boring Steady.**—A form of steady employed to guide boring tools in the lathe. One type is that for flat tools A and B, Fig. 39, in which the holder has a flat slot, and is held by its round shank in the socket of a rest clamped to the lathe bed, close up to the work. The design used for round bars, reamers, &c., employed in boring on a **Chucking Lathe** will be found under that head. A similar

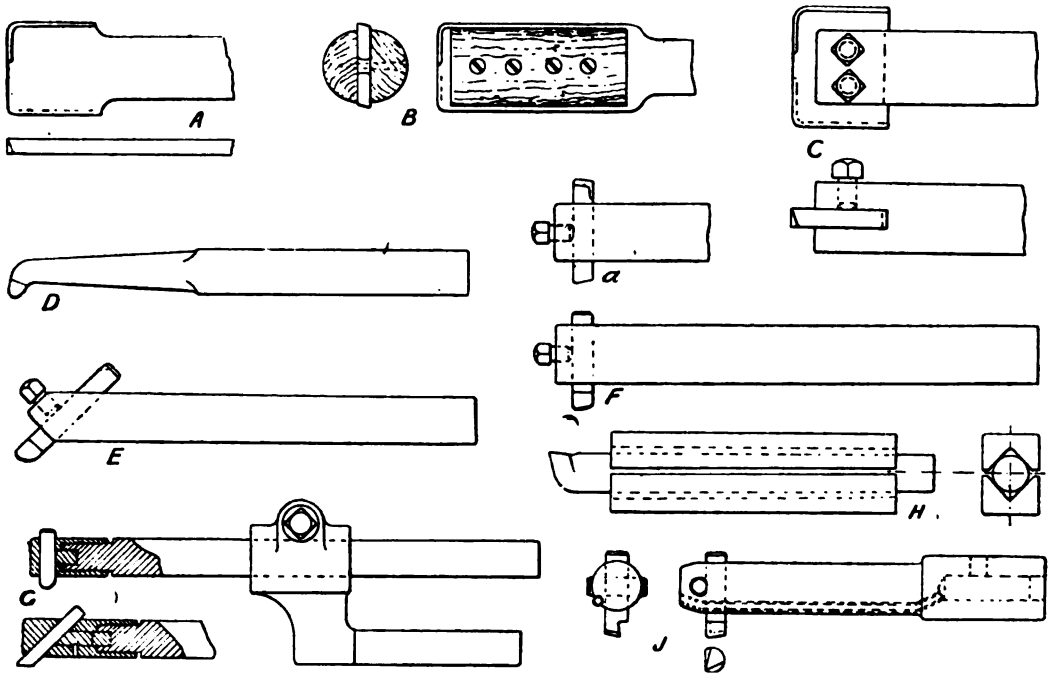


Fig. 39.—Examples of Boring Tools.

class of rest is employed for vertical chucking machines, or boring mills.

Boring Tools.—These, used in the lathe, and drilling and boring machine, are varied according to the service required and the size to be bored. The simplest form, the boring bit,

Fig. 39 A, made from flat bar, is used for lathe work; it is not a very accurate tool, owing to its lack of guidance, which permits wandering in irregular holes. To steady it the flat slot boring rest is employed. In use the tool is pushed up by the back poppet, the rest preventing rotation. In an improved type, wood slips are screwed on the flat faces, to fit in the bored hole and steady the tool, Fig. 39 B. To economise tool steel, cutters are most frequently held

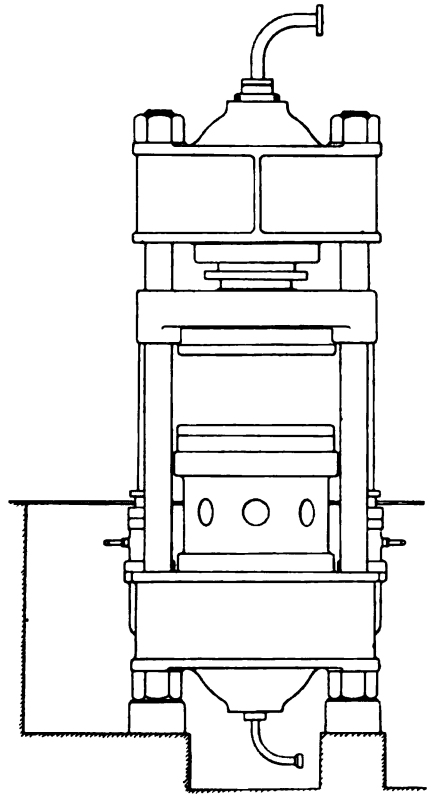


Fig. 40.—Bossing Press. (Fielding & Platt, Ltd.)

in a bar, Fig. 39 C; this may be steadied in the boring rest, or clamped on the slide rest, or if of round section, held in a turret, or the ram of a vertical boring mill. Tools which are held only in the slide rest, or boring mill, and cut by one edge, are shown in succeeding illustrations. D is formed in a single piece, E has an inserted cutter, angled, to reach into the corners of blank ends; F has a cutter, single or double-ended, *a*, pinched with a set screw; H is a convenient method of gripping a round boring cutter, the clamping plates of the slide rest pressing on the vee blocks and holding the tool securely.

A tool designed for use in the tool posts of American type lathes is shown at G. The bar is clamped where desired in the split lug of the holder, which is pinched in the tool post. The tool point is held at the end of the bar by the slotted, and screwed cap, jamming it against a bit of hard steel, as shown, set in the bar end. A modification shown immediately below, enables cutters to be held at an angle.

For work in wrought iron or steel, boring tools are often made with either tubes or holes to carry lubricant to the point; an example is seen at J, with a tube let into a recess. Oil is pumped through, cooling the cutter and washing out the chips.

Boring tools are very liable to dig in, so that top rake is either dispensed with, or made very small in amount, unless the tool is short and stiff. For boring very deep holes a special form of tool is employed, see **D-Bit**.

Boss.—Denotes a piece in a framing of mechanism which is pierced for the reception of a shaft, axle, spindle, pin, or bolt. The term is properly restricted to the circular shape, a half round piece coming out from the side of an object being a lug. The necessity for bossing lies in the objection to increasing metal unduly, the boss affording a means of increasing thickness through, or depth without adding to the thickness of the metal in the main framing, or web. A boss may be cast, or forged with its framing, or be made separately and attached by bolts or rivets; cast bosses are frequently bolted to plated work.

Bossing.—Signifies the formation of a boss on a forging by upsetting, welding, or finishing to shape. It is also applied to the turning of the bosses of levers in the lathe, or on a drilling and boring machine.

Bossing Press.—A machine designed for closing the forged bosses round the arms of the wheels of railway wagons. One of these is shown in Figs. 40, 41, the first giving an external elevation of the press; in the second the dies are shown in section. The lower one is supported on stools, not indicated. The action of the press is as follows:—The machine has two

rams moving vertically. The top one brings the dies together, and also partly finishes and forges the boss, the lower ram then rises and completes the operation. The dies are held together by the excess of power which the top ram has over the lower one. The machine will boss 15 wheels in an hour, or as many as can be supplied by two furnaces. The actual pressing only occupies a few seconds.

Boss Tools.—The term applies to two classes of tools, those used by moulders, and by smiths. They will be found described under **Moulders' Tools, Smiths' Tools.**

Bot Stick.—The iron bar which is used to open and close the tap hole of a foundry cupola. The closing of the hole is termed botting.

Bottle Jack.—A light form of screw jack with handle at the side.

Bottle Tight.—Denotes the absolute tightness of all the joints of a steam boiler, which when subjected to test shows no sign of leakage.

Bottling up.—The temporary confinement of the steam in the tubes of a water-tube boiler, due to its too rapid generation and accumulation.

Bottom.—A term which in the form of a prefix is applied to many things. The bottom card of an indicator diagram is the lower one for a vertical cylinder engine. The bottom face, or bottom part of a mould is that rammed in the sand floor, or in the bottom box. Bottom tools are the tools that go in the anvil in smith's work. Bottom rake is the rake of the lower, or front face of a tool, and is the same as the angle of relief.

Bottom Board.—A board used by moulders for ramming a pattern or part of a pattern on, instead of laying the latter on a temporary bedding of sand. This is the elementary function of such a board, but in various guises and under different names it is one of the most valuable aids to the moulder. The terms joint board, follow board, turn-over board, match board, match plate, denote its functions, and plate moulding, and machine moulding include the use of such aids, in which a metal plate is usually substituted for the board. Moreover to the function of jointing is often added that of the formation of runners. In the highest forms of plate moulding, two plates are used, a separate one for each half of the mould, as will be illustrated under **Machine Moulding.**

Confining our remarks here to the plain bottom or joint board, the pattern, or half pattern as the case may be, is laid upon the

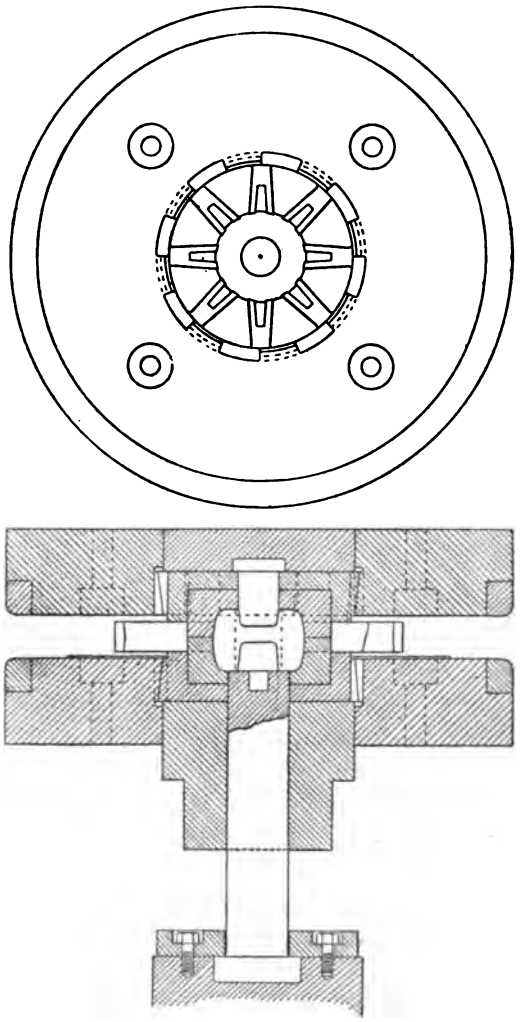


Fig. 41.—Dies of Bossing Press.

face of the board, and the bottom box laid over the pattern resting on the board, and rammed. This supplies a true joint face, upon which, after the turning over of the bottom box and removal of the board, the top box is rammed.

These boards are made in many sizes, square, and oblong for general use in the foundry; they are also fitted specially to certain boxes, the pins of which enter holes bored near the edges. The thickness of stuff ranges from about 1½ in. to 3 in., according to area. Generally, narrow boards are used to lessen shrinkage and warping, and battened. This will only permit one side of the board to be used for ramming on. Another device is to clamp a board between top and bottom box, and ram both box parts against the board in turn, Fig. 42. Then, when of large dimensions, the board is made by crossing strips nailed together and secured down the edges with thicknesses of hoop iron, screwed on flush, and through which the holes for the box pins are drilled. In such a case the pattern parts are fastened permanently to the board, so that the latter is not available for any other job, as it is in the first instance named.

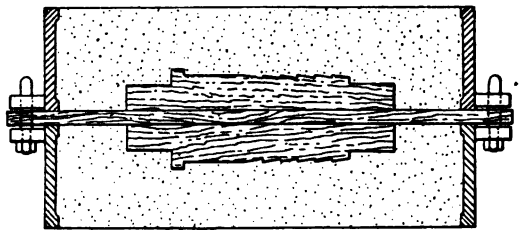


Fig. 42.—Bottom or Joint Board clamped between Box parts.

A bottom board may have blocking piece attached to its face, fitted either to afford support to a flimsy pattern, or to make the moulder's joints, or both may be combined. Good examples of the first named are afforded by gutter patterns, and by curved corner tank plates; the moulder's joints may be made in the bottom board at the same time, saving sleeking down, or making up sand to follow the pattern outlines at ends or sides.

A type of bottom or joint board used largely by brass moulders is that in which the board is pierced to receive patterns of circular or similar forms that are not jointed. As such solid patterns cannot therefore be laid on a board, they are let into it and sunk down until their parting line is flush with the face of the board (Fig. 43) and so rammed. Then the joint board is removed, and the top box is rammed on the sand face produced by the board, the pattern remaining as rammed on the board.

When we get beyond these devices, the term bottom board no longer applies strictly, but

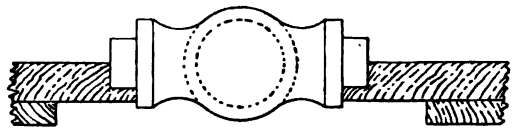


Fig. 43.—Recessed form of Joint Board.

the methods are those of **Plate Moulding**, or of **Machine Moulding**.

Bottom Clearance.—The space between the points and roots of gear wheel teeth.

Bottoming.—Denotes the rubbing together of the points and roots of gear wheel teeth, which happens if they are set too deeply in engagement.

Bottoming Tap.—*See* **Taps.**

Bow Connecting Rod, or **Banjo Frame.**—A form of connecting rod used much in small steam pumps, its value lying in its compactness of form. It is of triangular shape, and its triangular bow encloses the crank which drives the fly wheel.

Bowling Hoop.—*See* **Furnace Flues.**

Bows.—Small compasses used by draughtsmen, also termed spring bows.

Bow Saw.—Sometimes known as a frame saw, or a turning saw. It is a thin, narrow, parallel saw, used by wood-workers for curved outlines. It is secured at each end in a frame, Fig. 44, which subjects the saw blade to sufficient tensile strain to prevent it from bending. To enable the frame to clear the work wherever possible, the handles, and the saw with them, can be revolved into any position

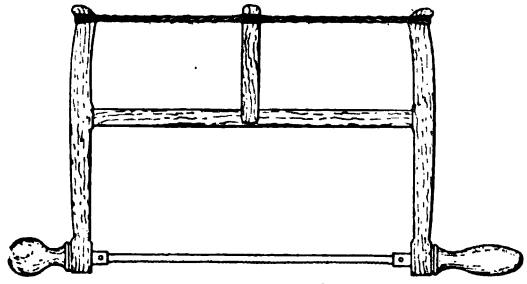


Fig. 44.—Bow Saw.

with regard to the frame. Thus, instead of the frame being at the back of the blade as shown in the figure, it could be swung to one side, or to any angle in relation to the direction the saw cuts in. In cutting down a plank, or round a large ring, for instance, it is obvious that it would be impossible for the saw to proceed very far with its frame following it as in the figure, but by turning the frame to one side, the saw would travel an unlimited distance as long as the distance from the saw-cut to the nearest outside edge of the wood did not exceed the amount the frame was large enough to clear. The usual method of tightening the blade is by means of a twisted cord as shown in the figure. Twisting the cord pulls the outer ends of the frame together, and as the frame is maintained at a fixed distance at the cross-bar, the other ends, next the saw, are strained outwards and keep the blade rigid. Bow saws are only used when a band saw is not available.

Bowstring Bridge.—*See* **Bridge.**

Box.—The term has various meanings. It denotes a box coupling, or a muff coupling, that is one made as a parallel hollow cylinder held on its shaft ends with keys. A bearing is often termed a box, especially in America, hence the term box metals applied to bearing metals. A box end connecting rod is one with a solid end, as distinguished from a strap type of end. A box girder is a solid-plated, or tubular girder, with double webbing of plate, as distinguished from a double lattice girder. A box link is a slot link having its internal faces recessed for the die block. A box nut is one with a closed end to protect the thread. A box safety valve is a bonneted valve. A box spanner is one recessed in a solid end to cover the nut. The box framing is the hollow framing adopted for machine framings, and engine beds. A box pass is an open groove of rectangular section in the rolls of rolling mills.

Box Boiler.—A term applied to the old rectangular boiler used in marine service.

Box Filling.—The floor sand of a foundry which occupies the principal space in a moulding box, and is so distinguished from the facing sand which comes next the pattern.

Box Framing.—Signifies the hollow design now nearly universally adopted for the framings of machine tools and machinery in general in place of the older ribbed framing. Rigidity without material increase in metal is thus secured.

Boxing up.—A term used in pattern-making to signify the construction of a bulky pattern in the form of a hollow box instead of solid wood throughout. It is a method of construction adopted because it makes a light and rigid pattern, not liable to warp and shrink. The term is applied only to patterns that are closed on all sides. A pattern that is open at any part and intended to leave its own core is not a boxed up pattern, although it may be in box form, minus of course a top, or side, or end. It is simply made the same as its casting. With a boxed up pattern the interior of the casting is cored out, except in the unusual case of a solid casting being required from a pattern large enough to be boxed. Boxing up is employed not only in building up rectangular forms, but in all others where the section is large enough to make a solid pattern undesirable. The extra time involved in boxing up is not usually very great, and the pattern is more permanent, and more easily handled, to say nothing of the material saved. The patterns for beds, hollow standards, and frames, box supports for machines, and all large hollow castings that are more or less closed on all sides, are boxed up, and cored out.

Curved work only differs from straight in having to be built up of a number of short pieces to follow the curve, instead of one straight piece. These short pieces are securely held in their position by the side pieces, of which they form the profile. The pieces which make up a curved outline are worked to the curve only on the outer face of the pattern, and are left straight and rough inside. Each piece is of course made as long as the thickness of the wood will permit, and the thickness used for cutting sweeps should be more than the thickness used in straight parts, or else the sweeps will be too thin in their thinnest parts. Partitions or cross ribs are also inserted at intervals in the interiors of boxed up patterns when it is advisable for stability.

The right way to box up is to let the sides that have to slide up past the sand on delivery run right from top to bottom. The wrong way is to let top and bottom pieces run right across.

Box-making Machinery. — Boxes and packing cases of all kinds when made in large numbers are generally produced entirely by machinery. There are a number of different machines for performing the various operations, and these vary according to the size and class of box they are intended for. The machinery employed may be classified as follows :—Nailing, Lock corner cutting, Setting-up machines, Hinging, Trimming and Strapping machines, machines for printing designs in colours on the wood, and in addition to these, some others that might be employed for general woodwork, such as sawing, planing, board-matching, and sand-papering machines.

Nailing machines come first in importance. They are made in sizes suitable for the boxes they are intended for. The smallest are designed for nailing cigar boxes. Some of these are only constructed to drive one nail at a time, while others will drive as many as five if desired. The heavy machines for large cases are made to drive a greater number, sometimes as many as thirty-two at a stroke, but they are usually arranged so that any number from one up to the limit can be driven as desired. The machines are provided with tables for the boxes to rest on. These are adjustable for height, and are provided with fences for keeping the wood in position. The nails are fed from a hopper above, and are held straight by chucks, and driven by a vertical movement of punches.

The machines for large work are generally provided with a table which permits large boards to be placed in any position, so that cleats or battens can be nailed across them at any place desired. For clinching the nails in battens some tables are provided with a hardened steel bar which can be sunk below the table level to allow the points of the nails to go through the wood, and can then be raised to bend them up level with the surface. For nailing cleats and similar work, two lines of chucks are sometimes arranged to drive two parallel lines of nails, either straight or zigzag. The number and the size of the nails can also be automatically changed at alternate strokes to suit the work the machine is doing. For the more expeditious nailing of bottoms on boxes, machines are often fitted with a side arm so that a row of nails can be driven in along one side of a box, and a row at right angles to it across one of the ends simultaneously. Two strokes instead of four are then sufficient to nail a bottom on. In machines with one straight row of chucks, where the part to be nailed is adjusted by pressing it against a fence, the fence has to be made adjustable so that for different thicknesses of wood the line of nails can be arranged to come in the centre of the thickness. Very often this is changed automatically at alternate strokes to suit boxes with thin sides, and thick ends.

Machines for cutting lock corners generally cut both ends of a pile of boards simultaneously. This ensures uniformity, and is a rapid way of working. There must also be easy means of adjustment for different sizes of wood. The cutters are a number of plates keyed on a shaft. These plates, which revolve with the shaft, have cutting edges something like large circular saw teeth. These teeth are the same thickness as the spaces to be cut, and they are kept at the correct distance apart by washers. Lock corner boxes are generally held together by glue, or sometimes merely by their tight fit, and the nails on bottom.

For putting these boxes together a setting-up machine is employed. The sides and ends of the box which is to be put together are placed within the jaws of the machine, without entering the corners, and the pressure of a foot lever then squeezes them all together and ensures the corners being square.

Hinging machines are used for hinging box lids on with wire hinges, a process which when done by hand naturally takes a great deal longer and increases the cost of the boxes. The machines have two tables, adjustable in relation to each other, and on these the box and its cover are laid in their correct position. The wire is carried on spools. From these it is cut, pointed, and bent into staples by the machine, which then forces them through the

wood at the places where the hinges are required, and clinches the ends, the pairs of staples which oppose each other being linked together, forming a hinge.

Machines for trimming or dressing the corners of either lock corner, or nailed boxes, and the overlapping edges of bottoms and tops, are of two types; one with a sliding plane, and the other with revolving cutters. In the first case the plane works vertically, cutting on its downward stroke, and the box rests on a low table on which it can be moved about to bring the parts desired against the plane. Usually two planes are fitted, adjustable in relation to each other, so that two corners may be trimmed simultaneously. In the revolving cutter type the box is placed on a sliding frame which carries it past the cutters, and thus each corner is trimmed in turn.

Strapping machines are used for binding hoop iron round soda water and similar boxes. They consist of a revolving frame in which the box is fixed, and a tension arrangement for keeping the hoop iron tight. The hoop iron is fed from a drum mounted in a convenient position near the machine. Generally two straps are put round the box simultaneously. The end of the hoop iron is nailed in place by hand, and then the strap is stretched round by a turn of the machine, and the other end nailed. The strap is then cut to length with shears, and the box taken out, and the intermediate nails put in at a nailing machine.

Machines for printing on the wood are used as an alternative to pasting paper on. From sixty to eighty boards a minute may be printed by these machines, and two or three colours may be employed by having a machine with a corresponding number of cylinders and ink fountains.

Matching machines are used to tongue and groove the edges of boards which are to be glued together. On large boxes, jointing in this way is often necessary. If the wood is thin, a single tongue and groove is sufficient, but if it is thick, and especially if it has to be resawn, a number of tongues and grooves are cut. An arrangement for applying glue to the joint is sometimes fitted to these machines.

When boxes have to be neatly finished, a sandpapering machine is used after the trimmer. This is chiefly employed for small boxes, and may be of the ordinary disc type, the box being held in the hands and each face brought in turn against the paper.

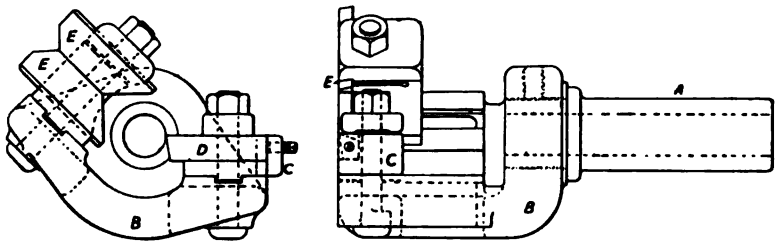


Fig. 45.—Common form of Box Tool. (A. Herbert, Ltd.)

Box Tools.—The principal feature of these special tools, used in hand turret lathes, and automatic screw machines, is the provision introduced for cutting to fixed sizes on repetitive work. The tools are clamped rigidly in boxes or holders, so that they cannot shift—the only alteration which occurs being that due to the wear of the cutting edges. To ensure that the work shall not spring back, steadies are incorporated in the holders, being placed opposite to the tools, in a similar manner to ordinary lathe steadies. Both these and the tools being adjustable for diameter, the size of the piece turned may thus be governed within very close limits, adaptable therefore to interchangeable methods.

The design of boxes permits of many valuable variations being effected, especially for shouldering work, and for facing. The former may be done to finish the piece, thus turning two diameters simultaneously; facing can also be done in the same operation. Centring, drilling, recessing, and knurling are performed with tools gripped in boxes. Cutting-off, screwing, and tapping are effected by other tools, which are not usually classed as "box" forms.

The simplest and most common form of box holder is that shown in Fig. 45. The round

shank A is held in the turret hole, and screwed into the box B. The latter has a flat way upon which the tool block C is clamped; C is recessed out to receive the tool D, gripped with the clamping plate above, and the long bolt passing right down through the box B, fitting in a slot, which allows of longitudinal adjustment of the tool block, and the use of another also, when necessary. The simplicity of the cutting tool may be noted, consisting of a bit of square bar, ground suitably at the end, and involving no forging. It does not possess top rake, the upper surface being radial to the work centre. Such a tool is capable of a surprising amount of slogging, combined with endurance, due to the end of the work as the box arrives at the termination of its traverse.

To get the most accurate results from box tools, two are employed in succession—one roughing down, the other finishing subsequently. The duty of the latter being very light, it will remain in good condition for a very long period. To enable these tools to commence a considerable reduction upon the end of a piece, it must first be pointed or tapered down to the diameter which the box tool cuts, otherwise the steady will jam against the work, or difficulty will be experienced in getting an accurate start. In hexagonal and octagonal bars especially is this pointing essential. A "starting tool" is used

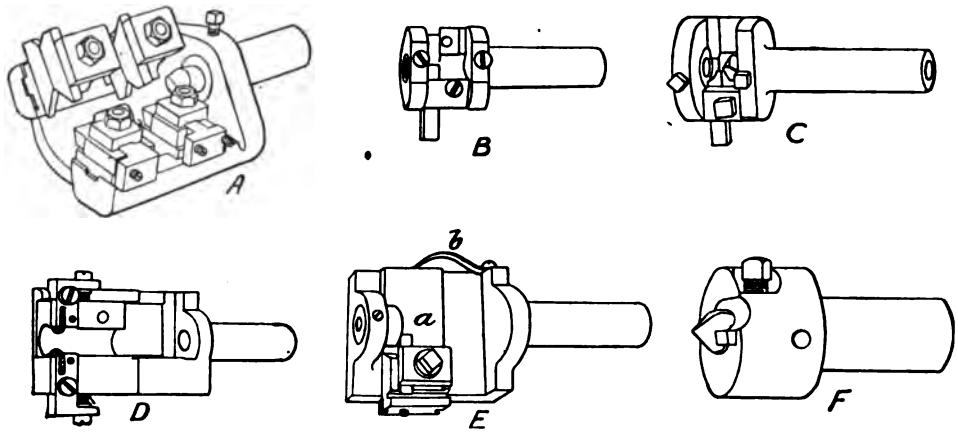


Fig. 46.—Various Box Tools.

its adequate support, and to the ample lubrication which is provided. The two vee steadies E, E, are located opposite the tool, and are gripped with the single bolt tightening down the split block upon them. The bevelled edges of the steadies prevent them from falling outwards. A good range of diameters is provided for by the large and small vees on opposite ends of E, E.

A similar class of box, but carrying double holders and steadies, as well as an end facing tool, is shown in Fig. 46, A. The front holder has a single tool set for a certain distance, and the back one a couple, adjusted for two other sizes, so that a shouldered piece of three differing diameters can be finished at one traverse. The facing tool held in the shank cuts for the purpose, having three cutters coned inwards, so as to cut a short taper.

Sometimes in place of the vee-shaped steady strips, a plain round hole, bushed with steel, first encounters the work, and the tool immediately following, commences to cut. The steadying effect is thus given to the bar before the turning is done, which is very suitable for bright-drawn bars, that can be relied on for uniformity of gauge, so that they fit the steady bush without shake. A box tool of the bush type is shown in Fig. 46, B. A tool for pointing or cupping work is seen at C. D is a knurling box, having two adjustable knurls, which operate on both sides of the work, and so balance each other. For turning short tapers box tools can be utilised, by fitting the tool to

a cross working slide, and coercing this by a former mounted on any convenient portion of the lathe,—as the cross-slide. E shows such a tool. The little tool-slide, *a*, can be moved across in grooved ways at a right angle to the work axis, the spring *b* pressing it against the form continually. A similar kind of mechanism is utilised for causing a tool to cut recesses in bores. A centring and facing box tool F, is employed for either preparing the end of a bar for subsequent operations, or for drilling and facing as a finishing process.

Boxwood.—A heavy, hard, close-grained wood, yellow in colour, and taking a high polish. It is used chiefly for wood engraving, and fancy articles, especially those turned in the lathe. It is also the wood of which rules and scales are made. Most of the box used for wood engraving is obtained from Turkey and the Black Sea district, where the trees attain large dimensions.

Boyle's Law.—The volume of a gas at constant temperature varies inversely as the pressure to which it is subjected.

Brace or **Stock.**—The hand appliance employed for turning bits. The form most used has a socket to receive the bit shank, a cranked handle for turning it, and a head which remains stationary and controls the direction of the boring or other operation performed by the bit. This kind of brace is made in considerable variety. Except in the simplest and cheapest forms, a ratchet arrangement is generally fitted which permits the brace to be worked backwards and forwards in arcs of a circle, and at the same time turns the bit only in one direction. The ratchet is usually made to operate in either direction, or be thrown out of use simply by turning a collar which controls it. Bits are held in the socket either by a catch which fits in a notch in the shank of the bit, or by a pinching screw, or gripped by jaws brought together by a taper sleeve which screws up and down on the body. Braces are now generally of iron or steel with wood heads and handles, the latter in the form of a sleeve on the cranked part. Formerly wooden articles with metal fittings were very commonly used. These kinds are employed chiefly for wood. An angular brace or stock is an attachment to an ordinary woodworker's tool which permits boring at an angle to the line of the brace. It is a lengthening piece with a knuckle joint, and is used for boring in awkward positions where even the ordinary ratchet movement cannot be employed.

Braces for drilling metal are made with two bevel wheels of different sizes; the large one being turned by the handle and the small one revolving the brace socket at increased speed. This attachment is frequently fitted to braces with the ordinary cranked handle, so that the tool can be worked by whichever method happens to be most convenient. This form is used for light drilling. For heavier drilling a form of brace in which screw pressure can be applied on the head is necessary to feed the drill. A form used for heavy drilling by hand consists of a ratchet worked by a lever instead of a continuous movement, and the necessary pressure on the drill is obtained by means of a screw and nut operating against a fixed arm.

Braced Girder.—A lattice girder.

Bracket.—A term of general application, signifying most frequently a casting or plated article of cantilever type that is supported at one end or face only. But the word is used very loosely, for almost any piece which cannot be classed as a beam or girder, or bed or plate is termed a bracket.

Brad.—A small kind of nail that was used more extensively before wire nails were introduced. It is cut from sheet metal, and is parallel in its thickness and slightly tapered the other way, while its head projects on one side only and is flush on the other three faces.

Bradawl.—A tool for making small holes in wood. Its cutting end is ground on each side like a miniature screwdriver, and it bores merely by being forced into the wood with a slight turning movement to alternate sides, thus forcing its way without actually removing material, as larger boring tools do.

Brad Punch.—A small nail punch used for punching the heads of brads and small nails below the surface after they have been driven level with the hammer.

Brake Dynamometer or **Absorption Dynamometer.**—A type by means of which the power absorbed by friction is measured.

The elementary form is the rope dynamometer, consisting of a pulley over which a rope is suspended. It is attached to a spring balance at one end anchored to a table, and to which the other weights are suspended, Fig. 47. If there were no friction when the wheel is at rest, the reading of the spring balance should denote the amount of the suspended weight. But the instrument is used to ascertain the loads produced by the revolutions of the wheel at different speeds, which puts the rope into the same condition as that of a belt transmitting power having a tight and a slack side.

The pulley rotating in the direction of the arrow (Fig. 47), the tight and slack sides are as indicated by T and S respectively. The

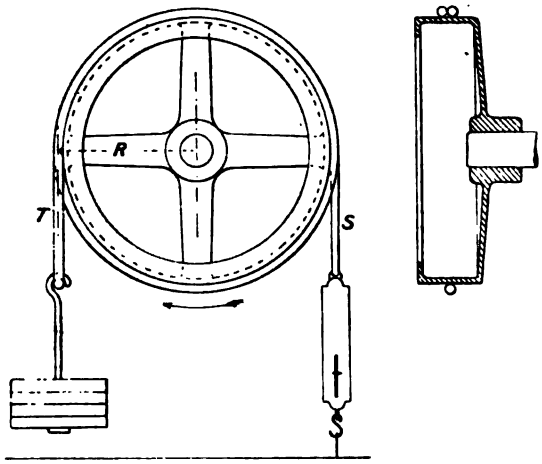


Fig. 47.—Brake Dynamometer.

effective brake load is the difference in stress between the two sides T and S, and the effective radius is the radius R, to the centre of the rope. It will often happen that the side S slackens, when the weight will fall back, restoring equilibrium. The rope may be turned round to embrace the pulley and the weights increased, which is favourable to a constant resistance. R being the effective radius in feet, W the effective load or weight, minus the reading of the spring balance, and N the number of revolutions per minute; then:—

The work done in a single revolution is $2\pi RW$,

$$\text{The horse power is } \frac{2\pi RWN}{33{,}000}.$$

It is necessary to keep the pulley cool by a supply of water.

A form of high-speed absorption dynamometer is made by Riehle Bros. of Philadelphia for absorbing from ½ HP. up to 30 HP. at 1,000 revolutions per minute. It is made to be coupled direct to the motor to be tested. No calculations are required beyond noting the velocity and the weights, which are supplied with the machine, and stamped for horse power. The dynamometer comprises a broad rotating band pulley carried in bearings low down in a framing carried on a base, made portable on wheels, to be taken to the motor. The total weight is 366 lb. The load pulley is 12½ in. wide, and the cotton band goes round its lower side, coming up to the load beam above, to which it is suspended parallel with the pulley diameter. The tension is obtained by suspending the load beam on a stirrup attached to a screw passing through a boss in the top of the framing. The pulley is set rotating by coupling its shaft with that of the motor to be tested. The counter is engaged, and the velocity noted, then the band is lifted against the pulley by means of a hand wheel connected to the stirrup above, until sufficient resistance is created to balance the beam with its load, when equilibrium is established between the motor and dynamometer. Weights are added at one end of the beam, the sum of which gives the power of the motor being tested, when the velocity is 1,000 revolutions per minute, which is the standard for the instrument, which with the maximum weight of 60 lb. measures 30 HP. The weight applied varies inversely as velocity, the greater the velocity, the less the weight. Thus, at 2,000 revolutions per minute, 30 lb. of weights will measure 30 HP. If the velocity be greater or less than 1,000 revolutions, the HP. will vary directly as the velocity.

Brakes.—These are appliances for the retardation of moving bodies; they have many forms and are operated by various means, but they all have the same essential principle, viz., the creation of a resistance which absorbs the energy of a moving body so as to reduce its speed and bring it to rest safely in a given period of time.

The leading types of brakes are dealt with

under their various names such as—**Electric Brakes, Hydraulic Brakes, Brakes—Railway, Strap Brakes, Vacuum Brake, Westinghouse Brake, Weston Brake.**

Brakes are operated by hand, foot, steam, compressed air, electricity, hydraulic pressure, or by automatic means, as using the energy of the moving body as a means of retardation. The following remarks take a general survey of the scope of the subject.

Hand brakes are used chiefly on crabs, winches, and cranes which are worked by manual power, and upon railway wagons. When applied to cranes and winches they usually take the form of a band or strap passing around a portion of the circumference of a pulley. This band is tightened upon the pulley by means of levers arranged to give the necessary power; for light brakes a simple lever is sufficient, but for more powerful ones compound levers are employed with screw and hand wheel. Steam cranes and winches have the same type of brake, but operated by a foot-lever—this is done in order to leave the driver's hands free to operate other levers; the treadle is usually fitted with a pawl to lock it in the "on" position. Some heavy cranes and winding gears have in combination with the treadle a hand wheel arrangement which is screwed down when the treadle is home, forming a means whereby the brake may be manipulated with fine adjustment and without undue effort on the part of the driver. The railway wagon brake consists of cast iron or wooden shoes which are pressed against the wheels by suitable lever arrangements operated either by hand lever, or by wheel and screw.

Steam and compressed air brakes are used on locomotives and trains; they are fully described under the heads above given. Electrically operated brakes although comparatively modern have developed in various forms. Ordinary strap brakes on electrically driven machines may be operated by means of electro-magnets instead of by hand or foot, but in such cases the function is reversed, *i.e.*, the brake is placed positively "on" by means of a weight or spring, and is relieved by the action of the magnet, the magnet winding being either in series or in shunt to the motor which drives the machine. The stroke of this class of magnet is usually 1 in. to 2 in., the leverage and lifting power being arranged to suit. With polyphase currents the brake lever is sometimes operated by a separate small motor which makes several revolutions during its action; it is geared to give a comparatively long stroke to the lever. Another form of electric brake is that where a spring produces end pressure on a series of discs which are feathered alternatively to the revolving shaft and to a fixed casing, the resulting friction being sufficient to prevent rotation; a magnet is then arranged to counteract the spring and so release the plates. Some tramcars and cranes are fitted with brake-stop controllers whereby the motor may be run as a dynamo driven by the energy of the moving car or the falling load; the controller resistances are then frequently used as a means of regulating the retardation.

There are also mechanical brakes which use the energy of the falling load in order to arrest it; they are known under the various names of Weston Brake, Washer Brake, Sellers Brake, &c. The originator of the brake was Weston. It consists essentially of a screw and friction discs arranged upon one of the gear shafts of the machine; the effect of the falling load is to force the discs together through the medium of the screw, one set of the discs being held from revolving, the resultant friction bringing the load to rest.

There are various forms of brakes used for testing the brake horse power of engines, but they more properly come under the heading of Dynamometers. A special kind of brake is used on board cable-laying steamers for regulating the laying of the cable upon the irregular bed of the ocean; it is usually a band or strap brake about 7 feet diameter, lined with wood, and arranged to run in a water-bath; the end of the lever is weighted to suit the tension required in the cable.

A simple form of automatic brake is used on various types of cranes; it consists of a strap brake with a weighted lever; the drum is in two portions, the outer portion upon which the strap operates being free to revolve upon the shaft, the inner part is keyed to the shaft and engages with the outer part by means of ratchet pawls which are effective only in the lowering

sense; the brake is thus always free to revolve in the hoisting direction, but the load can only be lowered by relieving the weighted lever and thus allowing the outer portion to revolve; it is in effect a combined brake and ratchet. Hydraulic brakes are used on various types of machines and heavy cranes; the principle involved is the regulation of the passage of water from loaded areas. Some testing brakes or dynamometers are water operated.

Brakes are most important details of lifting, lowering, hauling, and transporting machinery. Increasing weights and speeds demand better and more efficient means of coming to rest safely in a minimum period of time; and this not only on the score of safety, but as a time-saving device to accomplish a given journey or cycle of operations in a limited time. Modern high-speed electric cranes and like appliances have powerful automatic brakes fitted to every motion; and in many cases during a cycle of operations the period of acceleration has scarcely terminated in the acquirement of full speed when rapid retardation is effected by the brake; the few seconds thus saved on each movement make a considerable difference on a day's run or upon the accomplishment of a given task.

Brakes — Railway. — These are actuated by compressed air, by vacuum, and by steam. In the Westinghouse Automatic Brake compressed air supplies the power for working. It is forced by a pump on the engine into a main reservoir, from which it flows into a continuous brake pipe, and thence, through branches and triple-valves, to auxiliary reservoirs on the engine, tender, and vehicles. The triple-valves also control a communication between these reservoirs, and cylinders having pistons and rods connected to the brake levers. The continuous or main brake pipe extends from end to end of the train, and is united between the engine and tender and the various vehicles by means of flexible connections (metallic or rubber hose) fitted with iron coupling heads. Normally, an air pressure of about 70 lb. per sq. in. is maintained in the main-pipe, auxiliary reservoirs, and triple-valves, and the latter, by reason of this pressure, close the communication with the brake cylinders, and thus keep the brake out of action. On the other hand, whenever a reduction of pressure takes place in the main-pipe, the triple-valves move and allow the compressed air in the auxiliary reservoirs to immediately pass to the brake cylinders, forcing out the pistons and thereby applying the brake. A reduction in pressure can be made by either the driver or the guard, by permitting air to escape from the main-pipe by means of valves provided for the purpose.

The brake will also act automatically in the event of an escape of air owing to damage to the apparatus, or an accidental parting of the train.

So long as the full air pressure is maintained in the main-pipe, the brake remains out of operation; consequently, the brake is applied by decreasing, and released by restoring, that pressure. For illustrations of this, *see* **Westinghouse Brake**.

In the Vacuum Automatic Brake, the blocks are applied to the wheels by the pressure of the atmosphere acting on pistons, on each side of which a partial vacuum has been created by means of a combination ejector on the engine. The pistons are coupled by rods to the brake gear, and work in vertical cylinders enclosed in air-tight chambers called vacuum chambers, one of which is carried by the engine, tender, and each vehicle, and all of which are connected by flexible branches to a pipe running the entire length of the train. Communication between the engine, tender, and the several vehicles is effected by hose or other suitable couplings, and the brake coupling at each end of the train is closed by placing it on a plug provided for the purpose. Steam is continuously supplied to one portion of the ejector, which exhausts the air out of the train-pipe and brake cylinders, and thus creates a vacuum throughout the apparatus. Preserving this vacuum keeps the brake "off"; destroying it by the admission of air raises the brake pistons by atmospheric pressure and draws the blocks on to the wheels.

The brake is applied, therefore, by admitting air into the train-pipe, and released by withdrawing that air. This is done by the driver by means of air and steam valves on the ejector.

In cases of emergency the guard can apply

the brake by opening a valve fixed in his van. This valve also acts automatically whenever a rapid application is made by the driver.

The brake will be self-acting if any of the vehicles in the train become separated, or if any essential part of the apparatus is so damaged as to permit air to enter.

Application and release are effected by destroying and restoring, respectively, the vacuum *below* the brake pistons, that above them being necèssarily preserved in ordinary working. *See* **Vacuum Brake** for details.

When trains are provided with the vacuum automatic brake, the engines are frequently fitted with steam-brakes worked in conjunction with the continuous brake apparatus on the carriages. The steam-brake usually consists of a single-acting cylinder to which steam from the boiler is admitted through a valve fixed in the cab. *See* **Steam Brake.**

Bramah's Press.—The original form of the family of hydraulic, or more correctly hydrostatic force pumps, hydraulic presses, and jacks, invented by Joseph Bramah, in which the pressure of a ram of small area was made to operate a larger one, to exert an increased pressure proportionate to the difference in the areas of the two rams.

Brands.—Marks stamped on iron and steel plates and bars by the manufacturers to denote the particular quality of material. Also brands stamped by Lloyds, the Board of Trade, and other inspecting bodies to indicate the fact that plates, &c., have been passed. Also iron letters and figures on long handles which are heated, and by which timber, and timber work are marked.

Brass.—Brass is a generic term applied to any compounds of copper and zinc, as distinguished from the copper-tin alloys or **Bronzes.** These include a vast number of compounds, giving a wide range of materials, with different physical characteristics.

Brass is obtained by the direct admixture of copper, tin, and zinc, with sometimes a little lead added. In this way an exact and uniform product is obtained. But the metal mixers use large quantities of scrap brass, the composition of which is only judged of by the appearance of the fracture. Even though scrap should not be used, there is always a large quantity of sprues, fins, turnings, &c., to be remelted. So that in all foundries the practice is to melt these up with variable proportions of new copper cuttings obtained from the coppersmiths. This is how the largest amount of common brass is obtained.

This may not seem to be a very exact or desirable method, if judged by analytical standards, but in the hands of experienced melters it is as good as a more exact method, for all the common run of cheap castings. Without the employment of scrap brass and copper, it would be impossible to produce castings so cheaply as they are done. It is also easier than to make up new metal. In the latter, unless great care is exercised, liquation is liable to occur, while it is a fact that a given casting though nominally of one grade will be found to contain more than one grade of alloy, each solidifying at a different temperature.

Brass was made for a very long period by what was practically a process of cementation, which was at last displaced by the process patented by Emerson in 1781. In the earlier process metallic zinc was not used for admixture with copper, but the ores of zinc only—calamine chiefly—hence the term "calamine brass." Blende was sometimes employed, its use dating from 1758, called "black jack," and also known by other names. The calamine, or blende, first calcined and finely ground, was mixed with pulverised coal, and passed through a sieve having eight holes to the linear inch. The proportions used were five of calamine to two of coal. The mixture was heated with water, and passed through a sieve of four holes to the inch, mixed with bean shot copper, placed in clay melting pots, and set on the melting floor of a domed furnace built of firebrick and measuring about 3 ft. 6 in. both in diameter and in height, fired with coal, that became coked during the process, which lasted from ten to twelve hours. The copper was not allowed to melt until the cementation was complete, when the metal was fit to pour. The process did not die out until a good while after the Emerson patent appeared. Even this patent did not discard the calamine wholly, in favour of metallic zinc. Copper and zinc were

the principal ingredients, but a small portion of calamine was retained to confine the spelter by its own weight, and it was frequently omitted.

In making brass by the method which has been employed since 1781, the copper is melted first, and the zinc added, being broken into small pieces and added gradually to prevent volatilisation, and stirred. It is then ingoted, and remelted. If old brass is used, this is melted first, and copper added, followed by the zinc introduced at intervals, first being warmed. After the zinc has been melted, the metal is covered over and left for a few minutes in the fire before pouring.

As zinc volatilises in some degree, it should be added in excess of the amount required, and every remelting will lessen the proportion of zinc.

Rapid oxidisation is prevented by covering the metal with charcoal powder, or broken glass, or borax.

The brasses range from those which contain but a small proportion of zinc alloyed with copper, to those in which 45 per cent. of zinc occurs. M. Charpy has ascertained experimentally the following interesting facts relating to these alloys.

Their physical properties depend on the percentage of zinc up to a certain amount. Tenacity increases until about 45 per cent. of zinc is reached, after which it rapidly diminishes, and at 50 per cent. the alloy is fragile. Extensibility, compressibility, and reduction of sectional area increase until 30 per cent. of zinc is reached, which represents the maximum, after which they decrease rapidly. The limit of elasticity and the hardness increase also similarly. By varying the proportions of zinc between 30 and 43 per cent. a series of brasses can be prepared which possess properties as diverse as those of different metals.

As is well known to workers in brass, tenacity is greatly increased by working, while annealing increases ductility. Annealing is very efficacious at 500° C. or 900° Fahr., and it may begin as low as 430° C. or 800° Fahr. It is only by several annealings that the drawing out of metal into thin cylindrical cartridge, and other cases is possible. Overheating or burning is destructive of brass, rendering it rotten. This occurs at a temperature of 900° C. or 1,650° Fahr. In commercial alloys of brass which contain 0·15 per cent. of tin, and 0·2 per cent. of lead, this takes place at a temperature below 800° C. or 1,480° Fahr. It is possible by careful balancing of working and of annealing, to increase the tenacity of bars and sheets to 38 tons per square inch.

Reference has been made in **Alloys** to the eutectic alloy, or fusible "mother liquor" of the parallel case of saline solutions. Now the copper-zinc alloys have several eutectic alloys. This is much more than an experimental curiosity, it is really fraught with interest to the practical man. For a low eutectic point, which means a low fusibility, is accompanied with weakness of the alloy in which it occurs. The presence of a eutectic with a high fusing point generally coincides with an increase in the strength of the alloy, though diminishing its extensibility. In one particular case the presence of two eutectic points is of great value. It occurs in plumbers' solder, for wiping joints, the pasty condition of which is due to the fact that these points are widely separated.

The complications which these eutectic alloys produce help towards a conception of what goes on in alloys of two or more simple elements. Copper-zinc alloys have four of these, and the curious point is that each one solution in solidifying leaves a solid deposit, and a fluid "mother liquor," and neither of these may unite with the others, so that a mass of an alloy is not homogeneous actually, but is a complicated microcosm of alloys. Professor Roberts-Austen instanced a case of this kind, in which the presence of base metals in an ingot of gold interfered so greatly with the assay, that though the value based on the latter was £965, its value as proved on the separation of the gold was £1,028, a difference of £63. This was due to the presence of the baser metals, and though not disclosed by assay, it could, as subsequent experiments demonstrated, have been discovered by an investigation of the freezing points in the cooling curves.

Another way in which the eutectic alloy explains certain well-known facts is illustrated in **Aich's Metal** and in **Muntz Metal**, the

effect of iron in each case being to diminish the fusibility of the eutectic, and so increase the strength of the alloy. In other words, where a weak alloy with a low eutectic freezing point has to be rendered stronger, if another metal is added to render the eutectic less fusible, that is the direction in which experimenting is most likely to give the results desired. It substitutes a search on definite lines for tentative and merely random efforts. It is therefore not only desirable to know the initial point of solidification, but the secondary ones also in every commercial combination of the copper-tin alloys. The same remark applies also, of course, to copper-zinc and iron alloys. In all these, though the action has not been understood, the fact has long been known that minute quantities, mere traces of some elements, such as phosphorus, arsenic, antimony, bismuth, lead, &c., have been capable of effecting changes in structure which were utterly inexplicable, because out of all proportion to their microscopic dimensions. In all these cases the presence of fusible eutectics offers an explanation, a remedy, and a basis for intelligent alloying. Dr David Watson gave the following illustration of the effect of small additions of iron and phosphorus in increasing the tenacity of brass :—

Composition of Alloy.	Tenacity per square inch.	Elongation.
Brass containing 70 per cent. of copper, and 30 per cent. of zinc, without addition - - - - - - -	20·2 tons	65½ per cent.
Same brass, with addition of 0·5 per cent. of iron - - -	24·2 tons	31¼ per cent.
Same brass, with addition of 0·5 per cent. of iron, and 0·1 per cent of phosphorus - - - - - - - -	26·5 tons	28 per cent.

"Brass" covers a very large range of alloys which differ in lesser or greater degree. Some of these are capable of withstanding the great pressures necessary in force pumps, others, like cabinet furniture, and the cheap water, and steam, and sanitary fittings, will hardly endure any stress. The mere turning of the cheaper water and steam-cock fittings into their tapped holes will sometimes cause fracture through the screw threads.

Good brass should average from 60 to 75 per cent. of copper, the rest being zinc. But so much cheap scrap is used of unknown composition, that the only way to be sure of getting good brass is to insist on having it mixed to specification from ingoted metals, or to subject it to tensile test. What is called ash metal is lower stuff still, being reduced from furnace ashes, skimmings, and sweepings, mixed with enough zinc or lead to enable it to be ingoted. The proportion of zinc or lead in cheap brass may thus nearly equal that of copper.

In mixing brasses the practice is to melt the least fusible metal copper first, and then add the zinc, and lead if the latter is also used. If they were all melted together the volatile metals would be largely wasted. Generally the copper is not dead melted, but only partially fused, and the zinc and lead thrust in without first melting them. Or another method is to melt the copper in one crucible, and the zinc and lead in another, or in a ladle, and then mix the contents. By whatever method the mixture is prepared the alloy should be ingoted before remelting for casting.

Repeated meltings change the composition of brass, due to the volatilisation of the zinc and the liquation of the lead.

Brass Castings — Patterns for. — The patterns for the use of the brass moulder are constructed similarly to foundry patterns in general. But in the course of time a brass foundry accumulates a quantity of metal patterns and core-boxes in a much greater degree than they are found in iron foundries.

The principal reason why metal patterns are used in preference to those of wood is that large numbers of moulds have to be taken from

them. The same patterns are being moulded from daily, for years in succession. Those made of wood are incapable of enduring such prolonged and constant service. Another reason exists in the small dimensions of the majority of these patterns. Numbers of these measure less than six inches in length. Another is that allowances for tooling are cut fine on all brass castings, and this renders the use of metal necessary. Finally, metal generally delivers more freely and cleanly than wood from the sand.

Brass is used generally in preference to iron for these patterns, mainly because iron is seldom cast in brass foundries. But the surface of brass is better for moulding from than that of iron. The latter has to be rusted, and varnished, or beeswaxed. Brass is fit for moulding when rubbed over with a blacklead brush.

Nearly the same observations apply to core-boxes as to patterns. But the latter are frequently made of a white metal alloy, costing rather less than brass.

Metal in patterns is always worth its first cost. Its mass is lightened when practicable by coring, forming hollow patterns. But the cost of metal is a mere trifle when spread over the numbers of moulds made. Very often too it is small by comparison with the amount of time spent in tooling and perfecting the pattern surfaces. Patterns of rather large size are more convenient for handling when lightened as much as possible. Accuracy and permanence of form for regular service are the first considerations.

Comparatively few patterns for brass are jointed. The reason is that jointed patterns develop overlapping edges in the course of service, due to wear of the dowel-pin holes. The resulting lapped edges in the castings are objectionable, being unsightly, or reducing the allowance for machining. This absence of jointing explains why large numbers of solid patterns are recessed into their bottom boards flush with their jointing plane.

Brass-Finisher's Lathe.—This is more usually of the chasing type, so that work may be screwed and otherwise finished completely at one setting. An example will be found under **Chasing Lathe**. The capstan rest plays an important part in effecting economies of production, especially in conjunction with a cross slide carrying forming tools. The poppet also frequently carries drilling or boring tools. The chucks used comprise the special Clam Chuck, the ordinary ones of two, three, and four-jaw design, used by general engineers, and the revolving **Valve Chucks**, which facilitate the tooling of work having more than one working face or opening.

Brass-Finishing.—This constitutes either a special department of a general engineer's factory, or an entire works, in cases where nothing but brass fittings are produced. The conditions are rather peculiar, because of the nature of the materials operated on, and the large amount of repetition done. The machine tools employed consist chiefly of special lathes, milling machines, and drilling machines. Both ordinary lathes, rigged up with special appliances, and the regular turret types are commonly used. The class of work lends itself to the use of special tools, although most of these are also applied to work in general, and will be found described in these volumes under various heads, such as **Box Tools**, and **Forming Tools**, while the machines occur under appropriate headings. No separate account need therefore be given here, since many of the brass-working tools differ only in angles of cutting.

In addition to the turning, boring, drilling, and screwing operations, polishing and buffing are done extensively, on mops, and polishing belts, charged with abrasive materials.

The photo., Fig. 48, Plate IV., shows a typical brass-finisher's shop, with capstan lathes in operation, benches for reception of the work as produced, and separate benches for fitters. The work is, like other manufactures, much subdivided, and men are kept at the same jobs continuously, not even fitting up complete valves, &c., but only portions, the whole being subsequently assembled in another department.

Brass Founding.—Brass founding is not quite the same thing as brass moulding, though both terms are commonly employed to denote the work of moulding, and of melting and casting. Moulding is done by a set of men, who though they pour or cast have nothing to do with the mixing and melting of the metal.

A moulder is not a founder unless he understands and has charge of the metal also.

The metal is treated under various heads as **Brass, Bronze,** &c. The present remarks have reference to the mechanical work of the moulder.

Brass founding stands as a craft apart from iron and steel founding in various details, notwithstanding that the methods of moulding are similar in each. The sand used is generally more porous, and less venting is done. There is less risk of blow-holes, draws, and scabbing, than there is in iron castings. The metal sets quicker, and therefore larger runners and ingates are used than would be used in similar castings if made in iron, and feeding is but slightly adopted. As the skin of a brass casting is required to be smooth and clean, plumbago is less used for facings than pea meal, or flour. The shrinkage of brass is greater than that of iron, and this has to be taken account of in making patterns.

In moulding work for brass, little bedding-in is done, and not much of jointing by the trowel, but artificial aids are adopted. Joints are made by bottom or joint boards, or by plates, even when the aid of moulding machines is not utilised. If joints of irregular outline are required, then these often have to be moulded by hand and sleeked with the trowel, but this labour is invariably saved when quantities are in question, by shaping blocks on boards or plates to include the irregular as well as the plain outlines.

To illustrate the methods of moulding available, a sample coupling casting is selected which might be, and is, moulded by either of the methods shown in succeeding figures, and these methods apply to most castings which resemble this, in requiring a top and bottom box part, and one sand joint, part of the mould to go in the top and part in the bottom. Simpler moulds are those in which all the mould goes in the bottom, the top being a "plain top," that is, one in which no portion of the mould appears, but which forms a covering only for the bottom part. The example here given is a stage in advance of this, but is not so complicated as a mould which requires a three-part box, and two sand joints.

The pattern is shown in Fig. 49, 1, as ordinarily made for moulding by "turning over" without any aids to jointing, for which the moulder's trowel is requisitioned. The mould lies with the print *a* downwards, after turning over, and it is poured in that position. The core made from a wooden box like Fig. 49, 3, or from a metal box, is set in the print impression of the portion *a*.

It will be noticed that it would be impossible to separate the sand from the pattern around the handles *b b*, except by jointing the sand along the central plane *c-c*. Many patterns are so jointed, but the method is not desirable in the illustration given. It is preferable here to use a solid pattern, jointing the sand first along the top face *d-d* (compare, with Fig. 49, 2), and thence jointing down to the centre plane *c-c* of the handles *b b*. To ensure easy delivery of the joint edges from *c* to *d* they are never made perpendicularly as indicated at *e e*, but on a good slope as at *f f*.

The first labour-saving development which can be adopted is the employment of a plain bottom board A, Fig. 49, 4, and a pattern jointed along the plane *c-c*. In such a case the lower half of the pattern is laid upon the board, and the bottom box part rammed over it, so receiving a plain joint face of sand from the face *c-c* of the board A. The board is now discarded, and the top half of the pattern, dowelled to the lower half, left in the sand, and the top box part rammed directly on it.

A method which is generally preferred, because it does not involve jointing and dowelling the pattern, is indicated in Fig. 49, 5. The solid pattern is sunk into a joint board A, so that the centre plane of the pattern shall come just flush with the working face *c-c* of the board. This method is adopted in numerous instances. The bottom part box having been rammed over the pattern, the joint board is thrown aside, and the top box rammed on the half of the solid pattern now left exposed by the removal of the board.

The next stage in advance is that in which the pattern is plated, Fig. 49, 6. That is, the halves of a jointed pattern are attached permanently to the opposite sides of a plate A, which is sometimes of wood, but more often of

metal. The function of A is to provide two joint faces for the top and bottom part boxes to be rammed on, one succeeding the other after turning over. The thickness of A has no influence on the mould, since the sand joints made on the opposite faces of A meet when the box parts are closed.

This is a good and very suitable method for

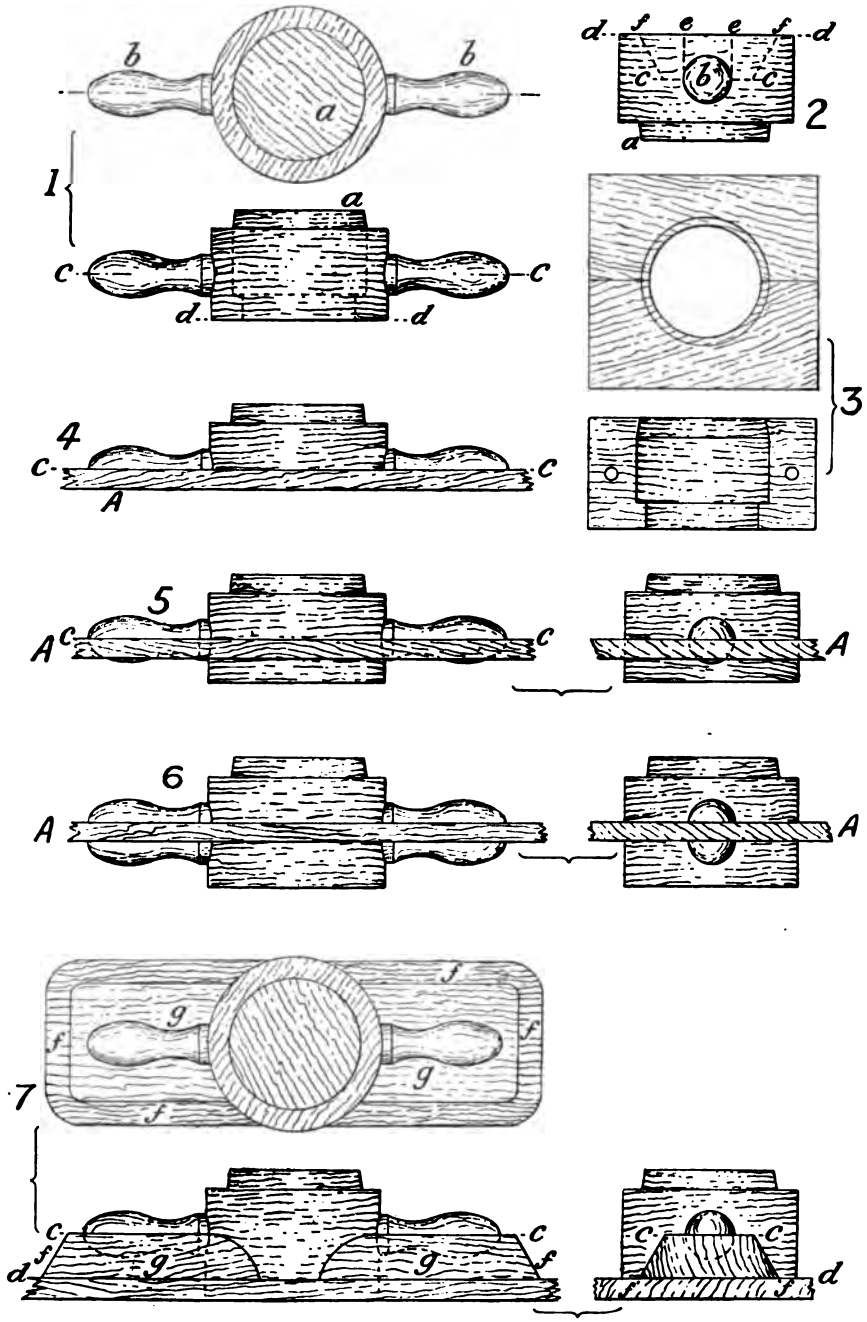


Fig. 49.—Brass Moulding—alternative methods.

the job shown. But keeping to the same illustration, another method which is also common is shown in Fig. 49, 7, given to explain the sloping form of joint. We saw in connection with 1 that a solid pattern around which a sand joint is sloped down to the centre plane *c-c* of the handles *b b* must have bevelled sides. Fig. 49, 7, shows how these are formed on a joint board, being precisely as they would be if the moulder shaped them in sand; the lettering *c-c* and *d-d* representing the same planes as in 1, as do also the slopes *ff* of the blocking *g* represent the similar joints *ff* in 2. The dimensions of the blocking, except the thickness, are of no particular importance, but the figure gives suitable proportions.

The spaces left in the mould by the block *g-g* can be filled by a mould rammed thereon, or taken from another joint board, either of which represents frequent practice.

Finally there is a stage in which the pattern parts are combined with the provision for making the moulder's joints on opposite sides of the same plate with which the pattern parts are cast. The plate thickness is nothing, the plate faces, flat and sloping, being the important details. A mould can be made from this by turning over, and ramming top and bottom box parts on opposite faces, and then the moulder has nothing to do but insert the core, cut the runners, and close the mould for pouring. Often, however, the runners would be formed on the pattern plate. In large quantities of work, sprays of runners and other arrangements are included on plates.

These examples are given to illustrate the principal alternatives available in the methods of brass moulding. But each one illustrates a method or a principle rather than details. Each one except the first is capable of much extension. Making moulds from single patterns is seldom practised except when the patterns are large, and comparatively little brass work is of large dimensions. Each one of the methods shown lends itself to repetition. There may be three, four, or twenty, or thirty patterns alike, or dissimilar in form mounted on a single board or plate by either of the devices here shown; the first excepted, because there the pattern is not mounted, but is independent. Yet even here economies are studied often by moulding several independent patterns alike or dissimilar in a single box, so filling it up. In moulding patterns in quantity on plates the brass moulder excels, and the bottom and joint boards have always been used more extensively in brass than in iron foundries. These methods will be found treated also under **Bottom Boards**, and **Plate Moulding**, since they are also adopted in iron moulding.

Brass moulders employ false cores to a much greater extent than iron founders do, who apply the term Drawbacks to the same class of device. The object of using a false core is either to avoid making a joint in the mould, or to avoid making a core from a core-box. False cores reach their highest development in statue founding.

Rather more care is necessary in arranging the runners of brass castings than those of iron, because brass does not remain fluid for so long a time as iron; and when a number of patterns are arranged in a single box, metal often has to travel a considerable distance to the farther moulds. These points have to be taken account of by giving sufficient cross section to the runners to enable the metal to remain sufficiently fluid to fill the most distant parts of the thinnest moulds.

Another difference in iron and brass founding is that vertical pouring to obtain sound castings, generally practised in iron, is not nearly so often adopted in brass. It is practicable to obtain sound liners, penstock screws, and similar pieces that have to be turned bright all over, by casting on the flat, if the runners are large enough and the metal properly fluxed. Skimming gates also are used freely in brass work, and prevent the entry of dross and light metal into the mould.

The moulding boxes used by brass founders differ in general from those employed by iron founders. The small dimensions of the work renders the use of large stayed boxes unnecessary. Hence we have boxes without stays or bars, ranging from 10 in. to 12 in. to about 24 in. square, or round. Devices are used to retain the sand, such as internal ribbing, and imparting a vee'd or a sloping section to the interior faces.

Another difference is that a good deal of brass work is poured through the ends of boxes instead of through the top, with the mould

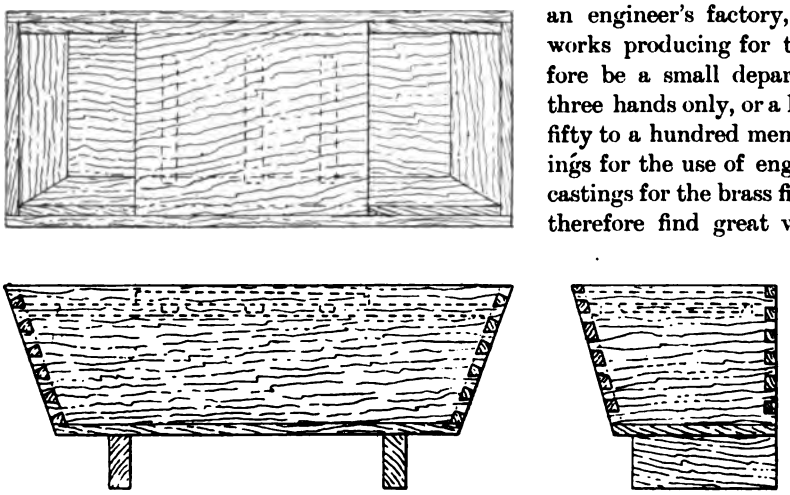


Fig. 50.—Brass Moulder's Tub.

lying flatwise. The moulds are poured thus to permit the boxes to be stood at a slight angle against the sides of a spill trough, the object of which is to catch the droppings of metal from the crucible and pouring basin, and so prevent them from getting buried in the sand of the

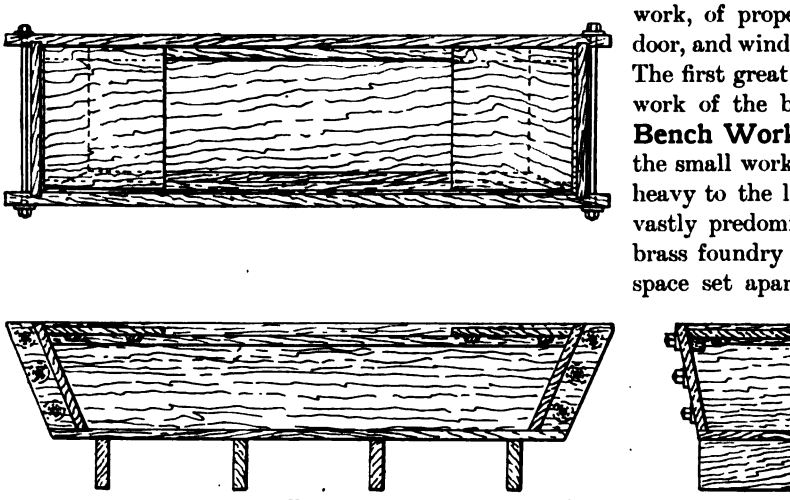


Fig. 51.—Brass Moulder's Tub.

floor. In such cases the boxes are clamped instead of being weighted. A large volume of brass work is of course also poured flatwise on the floor, and the boxes are then weighted as in the iron foundry.

Brass Foundry.—A brass foundry either forms a department among the larger shops in an engineer's factory, or it is an independent works producing for the trade. It may therefore be a small department employing two or three hands only, or a large shop employing from fifty to a hundred men and boys, supplying castings for the use of engineers, and providing the castings for the brass finishers of the works. We therefore find great variations and differences in its equipment as well as in dimensions.

The brass foundry has its resemblances to and differences from the **Iron Foundry**. The resemblances are those which result from methods of moulding and working, differences are due to metal and mass. Brass work is mostly light by comparison with iron, the principal articles being cocks, valves, gauges, bearings, and miscellaneous light castings of all conceivable shapes. Heavy work consists chiefly of castings for marine engines and their auxiliary machinery, of massive pump work, of propeller blades, of lighthouse door, and window frames, and large bells. The first great division therefore of the work of the brass foundry is that into **Bench Work**, and **Floor Work**, all the small work going to the former, the heavy to the latter. As the light work vastly predominates in most shops, the brass foundry generally has little or no space set apart for floor work, the area being free for casting over, and for sand storage.

In a well-managed shop the benches and furnaces, &c., are ranged along the sides, leaving the whole of the central area clear for casting on, excepting that a row of sand bins is frequently placed down the centre from

which the men can draw their supplies on turning round, without having to go down the shop for sand. Frequently the moulding tub, Figs. 50 and 51, with sliding cover, is utilised for moulding on.

The methods of green sand, dry sand, and loam are adopted in brass founding as in iron. The bulk of the work is done in green. Dry sand is reserved chiefly for castings that have to be very sound, and to withstand high pressures, and for those of large dimensions. Loam is adopted in sweeping up propeller blades and large bells. The dimensions of the core stoves used vary therefore, small stoves with shelves of sheet metal being used for the average small work, large bricked stoves with core carriages ran in from the level of the foundry floor for heavy work.

The equipment of the fettling room will also differ in the large and small shops, being larger and having more and heavier machines in the one case than in the other.

Furnaces of the crucible type are used in all brass foundries whether of small or large size, but the reverberatory furnaces are generally employed for heavy castings.

The methods of moulding in brass foundries are as varied as are those in iron. Hand work generally predominates, but this is nearly always assisted by the employment of bottom boards or joint boards. Frequently a large volume of plate moulding is done. In modern foundries doing a large or even moderate amount of repetitive standard work, machine moulding is adopted.

Though it is usual to speak of the work done as that of the brass foundry, it is understood that the term covers all work in the copper-tin alloys as well as that of the copper-zinc, and the phosphor bronzes. Brass castings, strictly speaking, find little place in engineers' work, most good fittings and general castings being in the gun-metals or the compound bronzes. Brass is used for the cheaper class of fittings as well as for work done in the trade, for cabinet-makers, gasfitters, builders, &c.

Brass Melting Furnaces.—With relatively few exceptions these are air furnaces, having only the natural draught of a tall chimney. They are mostly built of brick below the level of the foundry floor, and each melting hole—coke fired—contains but a single crucible.

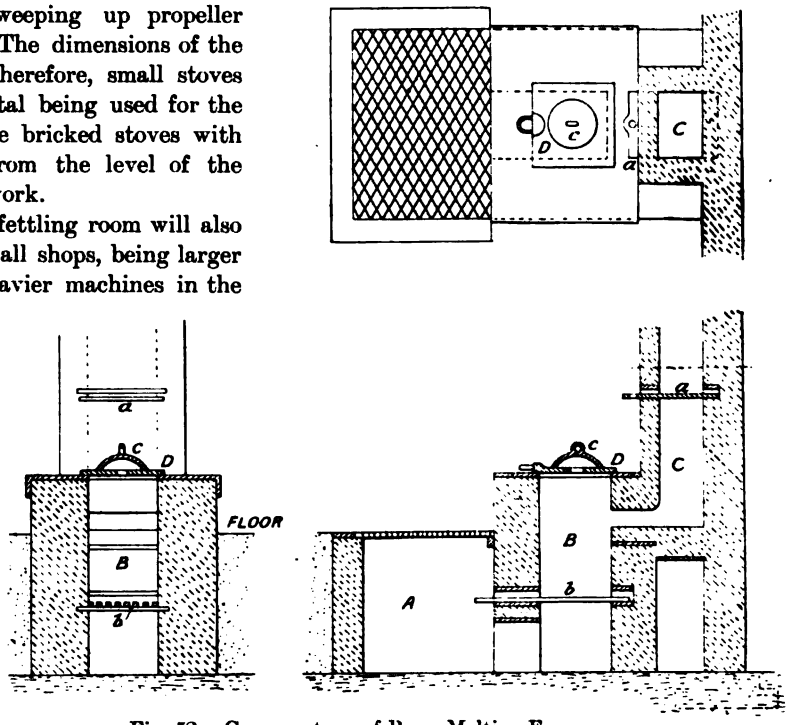


Fig. 52.—Common type of Brass Melting Furnace.

Of late years many modifications have been introduced, and used in some degree, but still in the majority of foundries the brass furnace has not changed in essentials or details for two or three generations past.

The common type, Fig. 52, is built wholly of brick-work in a pit below the floor, the tops of the furnaces standing only from 9 in. to 12 in. above the floor. The object of this is to permit the melter to stand well over the furnace, and to see the crucible, and lift it in and out readily. A pit A in front serves to draw the ashes out of, and being covered only with a

perforated iron grating, it permits the passage of air for draught. This is drawn down under, and up through the furnace bars and furnace B to the chimney stack C, which seldom need exceed twenty feet in height, for providing enough natural draught; a damper regulates the draught. One furnace must have its stack, but a single stack will serve for a long row of furnaces. A row is necessary in all but very small foundries, for several reasons, chiefly because it is not practicable to melt more than from 80 to 120 lb. in a single furnace. If therefore a larger quantity is wanted for a single casting, or for a number of castings, the number of furnaces has to be increased accordingly. And spare furnaces are necessary to permit of occasional repairs being done. The smallest furnaces measure about 12 in. square, the largest seldom exceeds 18 in. or 20 in. The sizes across are only a few inches greater than the crucibles, in order to economise coke.

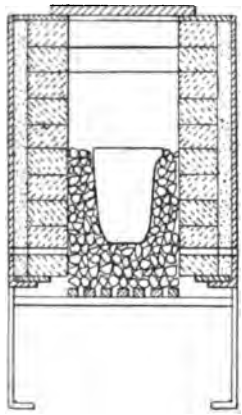


Fig. 53.
Carr's Portable Furnace.

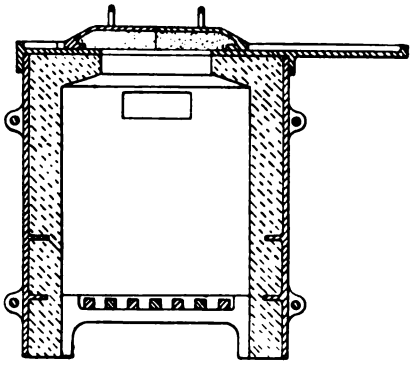


Fig. 54.
Square Portable Furnace.

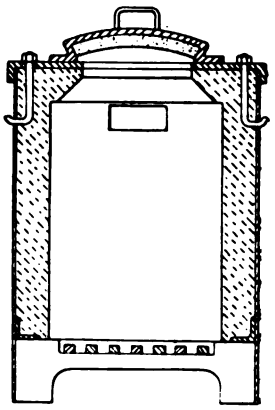


Fig. 55.
Circular Portable Furnace.

The furnace bodies are built of common brick, but the linings are of fire-brick set in fire-clay. The interior is lined with fire-clay, which lasts for a few weeks. The grate bars *b* are of wrought iron, laid loosely on a bridge piece built into the brick-work, and these bars are drawn out when the fire has to be dropped at the end of the day's melting. The ashes are thrown up into a wheel barrow above, or taken out through a culvert on the level of the ash-pit floor. The top of the furnace is closed during melting with a cover D and tile *c*. The latter only is removed during the melting, for the insertion of the poker through the small hole in the cover. The cover is only moved when the fire is being made up, and the crucible inserted or removed.

The furnace is charged with coke, which is allowed to warm the lining, and the brick-work, before the insertion of the crucible. This is laid on the bed of coke, pushed down and raked level, to give from four to eight inches between the top of the crucible and the top of the furnace. Coke is thrown in all round it, the cover put on, and more coke above, to the top of the furnace. The damper is then opened to allow a full draught, and by the time the coke has burnt down a few inches the brass will be melted.

Though this is the usual type of furnace, there are several other forms. Many of these are the rivals of the single furnace used in small shops, doing a light class of work only. Some are built on a large scale. It is, however, generally considered better when heavy work is being done, to use a reverberatory furnace rather than the produce of several crucibles.

The smaller furnaces are mostly of the so-called portable type, that is they are independent instead of being built of bricks rigidly in the floor. These generally utilise either gas, or an artificial draught. They occur in various guises. Some gas-fired furnaces

utilise a mixture of gas and air in measured proportions with means for ensuring combustion, others use gas alone, utilised in suitable burners. Means are sometimes included for carrying the products of combustion around the crucibles. In favour of gas there is the fact of its cleanliness, and its ready regulation.

Carr's portable iron furnace, Fig. 53, is made for chimney draught. Its two principal features are the lining of sand or fire-clay interposed between the casing and the bricks, to keep the iron cool, and the placing of the fire-bars below the bottom of the furnace. The object in this is to prevent the sinking down of the crucible, due to the burning away of the coke beneath it. Much of the air for combustion enters above the bars, so preventing the rapid burning away of the fuel.

A good many American portable furnaces have a square cast-iron casing formed of plates bolted together, Fig. 54. Others are circular, Fig. 55. Ledges are cast inside to support the brick-work. In the design, Fig. 54, there are upper and lower ledges between which the bricks that burn out most rapidly are located, so that they can be readily renewed without disturbing those above. In some furnaces the linings are made removable *en bloc*. There are numerous little details in these furnaces that are worthy of note, but which must pass without description.

Among the devices for superseding the ordinary furnaces are those with provision for utilising blast, and sometimes also for warming it. One of the best known of these is the Fletcher. In this there is an outer air casing surrounding the inner melting chamber, the walls of each being of sheet iron, or the outer one of brick, and the inner one lined with fire-brick. The blast is heated by its passage down the annular chamber, which also lessens radiation of heat from the melting chamber, and enters at the bottom through the grate, and so up through the flues.

A heating chamber has been fitted over this furnace for the purpose of warming the crucibles, being heated by the waste gases on their way to the flue. A secondary, though useful feature of these furnaces is the drop-bottom, which being operated by a lever, discharges the contents of the furnace without the bother of grate bars. The great advantage of a pressure blast is the certainty of the time of melting, and the economy of coke effected. As many designs of brass furnaces are used for melting other alloys, some of these will be found under **Crucible Furnaces.**

There are a good many designs in use to a greater or less extent, in which various valuable points are embodied. But somehow they do not displace the old furnaces from favour. Doubtless they will do so in time. A recent development which may extend is the use of gas, or of oil for firing. A battery of furnaces will be fired with gas, or single furnaces with oil. The practice is in harmony with the modern tendency to the displacement of solid, by gaseous or liquid fuel.

Reverberatory furnaces used in heavy brass foundries are indispensable when heavy lumps of old metal have to be remelted, being too large to be put into a crucible. The alternative would be making them red hot, and breaking them with a sledge in lumps small enough to be put into the crucibles. It is generally preferable to use this furnace for heavy casts rather than the produce of several crucibles. *See* **Reverberatory Furnace.**

Brattice. — A wooden partition running down a mine-shaft.

Brazing or **Hard Soldering.**—A method of union which differs from ordinary soldering in the harder character of the alloy used, and its higher melting point. The art of brazing is chiefly to have joint faces perfectly clean, the proper use of borax as a flux, and to arrest the operation as soon as the metal has run into the joint. The parts to be united are retained temporarily with binding wire, or other device, as the operation takes a considerable time. The borax is pounded finely in water, the spelter solder granulated, and the two mixed. They are applied separately, or together, and sprinkled, or spread along the joint with a spatula. The heat must be applied gradually, otherwise the boiling of the borax would displace the spelter. The heat is increased until at a low red the borax fuses, the solder at a bright red sinking into the joint. The volatilisation of the zinc in the solder is indicated by

a blue flame, which shows that the joint is finished. Equal parts of copper and zinc make a good brazing solder. Hardness is increased by increasing the proportions of copper.

Brazing Flange.—A flange cast in brazing metal to be brazed to copper or iron pipe. It is made just an easy fit over the pipe, and the pipe suspended vertically over a clear coke fire while the brazing is being done, the copper bit being useless at the high temperature necessary.

Brazing Metal.—An alloy of 2 only of tin to 98 of copper, used in casting flanges, &c., that have to be brazed to pipes, the high proportion of copper being necessary to avoid risk of melting.

Brazing Wire.—Soft brass wire used both for binding and brazing joints. The wire melts and runs into the joints.

Breakdown Crane or **Accident Crane** or **Permanent Way Crane.**—Denotes a type of balance crane used in general railway service, the most important section of which is the disentanglement and removal of the debris of accidents. It is sometimes a hand crane, sometimes driven by steam power. The essential difference, however, between this and the ordinary balance crane is that the truck work has to fulfil permanent way requirements; that is, the standard wheels, axle boxes, horn blocks, leaf springs, buffers, draw bars, &c., of a given railway must be fitted to the crane truck. Further, cast iron is not used for the main truck, or for side frames, but these are steel-plated to withstand shock better than cast iron. Blocking girders are generally fitted, sometimes a pair of jointed legs are added to serve as a strut to the jib head when the crane is being used to pull loads that might overcome its stability. Many cranes have six running wheels instead of four, some have eight, as in the illustration, Fig. 56, Plate IV.

Breakdowns.—These are liable to occur in all classes of motors and machinery, and the aim of persons in responsible positions is, first, to lessen the risks of their frequency, and, second, to execute the necessary repairs or renewals with the least possible delay.

There are cases in which breakdowns entail much less serious consequences than in others. The most serious are those in which motive power is concerned, as in the engines, or propellers and shafts of ocean liners, in locomotives, in the engines and dynamos of power stations, in mill and factory engines, and shafting. Of less relative importance are machines and machine tools, because the breakdown of one of these does not interfere directly with the working of others, whereas that of a motor may dislocate the operations of an entire factory or area, or leave a vessel or a train helpless for a while.

Breakdowns may be due to one of three causes: faulty material, or bad design in the first place, fatigue of materials due to systematic overstrain, or to the chapter of accidents which cannot be foreseen or provided for. They are remedied by repairs, or by renewals. To facilitate the latter is the reason for providing spare parts, or duplicates.

The first named, faulty materials and bad design, lie at the root of practice, and they involve inspection, calculation, and experience. There is no excuse for the neglect of either, save that of expense, which should not be allowed to have weight against the possible expense of a costly breakdown. Fatigue is a more insidious evil less capable of detection or calculation, but it may be checkmated by adopting the practice of allowing only a certain life for a member which is subjected to severe alternating stresses. It is done in railway practice by allowing a certain length of life only to axles, boilers, and other parts, and renewing them after a definite mileage. Though parts removed for renewal are often found to be as good as new, that does not render the general system less safe, nor excuse the practice which generally exists in private firms of running machinery until it actually breaks down.

There are many accidents which cannot be guarded against, those due to sudden and unforeseen overstrain, and those which arise from human stupidity against which the gods fight in vain. Because of these occurrences it is necessary to keep duplicate pieces of those parts which experience shows are most liable to give out, and to have arrangements for executing rapid repairs. Duplicate sets of complete motors are but of limited application on account



Fig. 48.—Brass Finishers' Shop. (Baldwin Locomotive Works.)

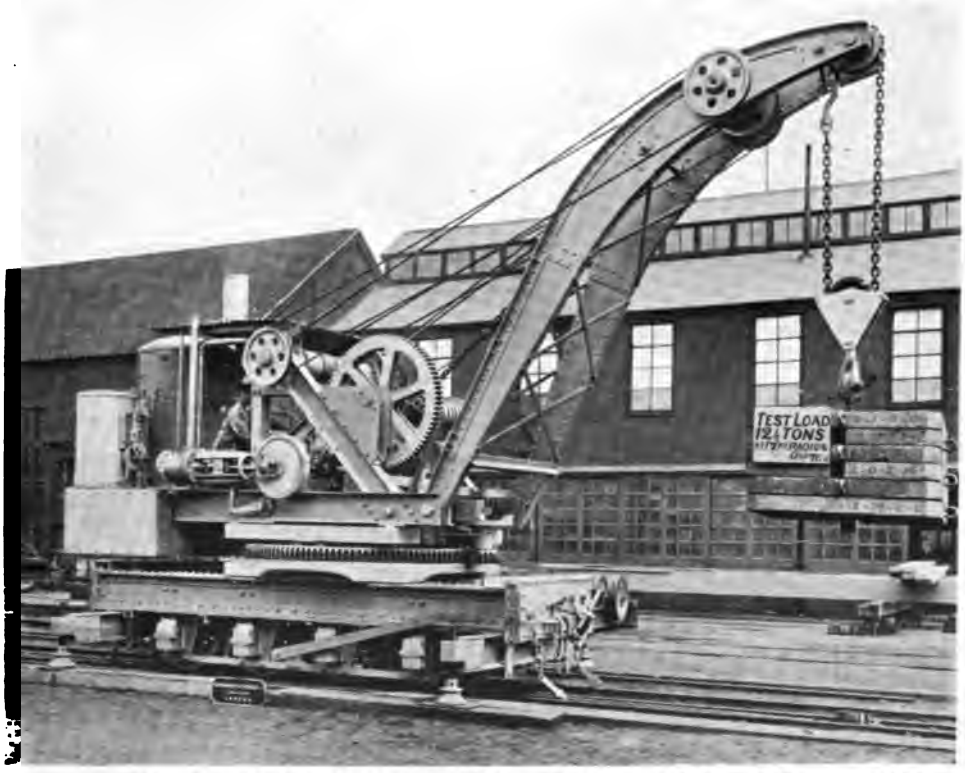


Fig. 56.—10 Tons Breakdown Crane. (Ransomes & Rapier, Ltd.) [*To face page* 66.

of their expense and the room occupied. In factories the system of running lengths of shafting by independent engines, or electric motors, or by friction clutches, enables the delay incidental to a breakdown to be localised instead of throwing a whole shop idle while repairs are going on.

The probability of the need for rapid repairs or renewals should be regarded in the design of machines, though it is a matter more often neglected, or given but scant attention. Those who have to effect repairs know that the less dismantling of adjacent parts is involved the more rapidly can the renewals be accomplished. It is often necessary to remove shafts and gears in order to get at something behind or below them, which removals might have been avoided by the exercise of forethought in the original design. Shafts often have to be drawn out endwise through their bearings, when capped bearings might have been substituted. The mere drawing out is nothing, but the getting shafts through gears, &c., that are keyed, and often rusted on, is difficult and tedious. The fitting of new wheels or pulleys might often be facilitated by casting in halves instead of solidly. The casting of hand holes in some cases, the insertion of rings or eyes in others, would often help the fitter.

Some of the breakdowns most difficult to deal with are those which take place at sea, as the snapping of propeller shafts, sometimes through the thrust bearings, the breaking of propeller blades, or the loss of an entire propeller. The annals of engineering afford many notable examples of repair work of this kind executed under unparalleled difficulties involving danger and prolonged fatigue.

Mr Michael Longridge, the chief engineer to the Engine and Boiler Insurance Co., compiled some very valuable statistics in a paper read before the Institution of Mechanical Engineers, relating to a thousand consecutive breakdowns of stationary steam engines which came under his personal observations. He made a careful analysis of these, and classified them under principal heads and subdivisions.

A list of the parts included in the main classification, with the number of cases in each is given.

Parts.	Number of Cases.
Valves and valve gear,	213
Spur wheels,	124
Air pump motions,	121
Air pump brackets and valves,	88
Columns, entablatures, bedplates, and pedestals,	86
Main shafts,	49
Connecting rods,	41
Cylinders and valve chests,	35
Parallel motions,	35
Governors and governor gear,	28
Piston rods,	27
Piston rod cross heads,	27
Pistons,	22
M'Naught and main links,	22
Flywheels,	19
Air pumps and condensers,	13
Cranks,	12
Gudgeons in beams,	12
Crank pins,	11
Beams,	6
Slide bars,	5
Ropes,	3
Entire smash, no cause ascertained,	1
	1,000

It was thus found that valves and valve gearing were responsible for the greater number of breakdowns. But for reasons to be presently given the proportion of failures of spur wheels, and of various fastenings, is not brought out to the full in the table.

Of the 213 breakages of valves and valve gear, the largest single cause was due to the weakness of screw threads, 34 fracturing through the root of the thread. The next big item was 24 eccentric straps, mostly from weakness in the lugs or bolts which joined the halves of the straps together. Rocking shafts and levers were responsible for 23 breakages. The working loose of nuts, cotters, and pins, for securing valves to spindles, was a fruitful source of trouble, 21 cases occurring. But this does not represent the whole story, since fastenings of this kind caused numerous accidents under other heads included in the list. So too the failure through the screw valve spindles is repeated in

9 cases out of 18 broken eccentric rods; 17 slide valves were broken in various places, and in 11 cases failure followed the breaking loose of strips of brass pinned to the edges of slide valves or ports.

Spur wheel failures are given at 124, but as this only takes account of the driving wheels on the main engine shafts, driven wheels or pinions being excluded, it only represents a little more than half the actual failures, so that these make a very bad showing. One of the practical results which has followed is that Mr Longridge's recommendation that the teeth of gears for mill engines should in no case be given a height exceeding half their pitch, has greatly modified the design of wheel teeth. Formerly most teeth were long, now nearly all are either short, or of medium height only.

The failures of spur wheels on prime movers are due to many causes. In the examples under consideration backlash was responsible for 23. Vibration due to high speed, heavy load, insufficient flywheel, and small pinions for 19. Teeth bearing on their corners for 16. High speed and irregular pitch for 11; and bolts or pieces of broken teeth got between wheels for 10. Only 7 cases of fracture from internal stress were reported, and these were mostly cast solidly, *i.e.*, not in halves. A small group numbering 5 fractured because of the small size of the pinions.

Air pump motions totalled to 121, of which 20 were due to crossheads breaking, a result following on severe bending stresses on journal necks too weak to stand them. 17 levers broke; and crank shafts, cranks, rocking shafts, and eccentrics made up 11 more. Of air pump rods 15 broke through the cotter hole or other parts, another case of the trouble arising from fastenings. These are followed by 18 cases of cotters in bucket rods and other parts of motions, and bolts coming out. 26 more cases follow of various fastenings getting loose and breaking.

Breakdowns of air pump buckets and valves total to 88, the principal among which are 32, due to foot valves and parts breaking, 21 to buckets jammed by worn packing rings, 15 to head valves breaking, 10 to bucket valves and guards breaking. Columns, entablatures, bedplates and pedestals failed from many causes. The largest evil was the settlement of foundations which produced 37 failures, and 12 were due to water in cylinders. In 18 cases the causes could not be ascertained.

49 main shafts broke down, nearly all of which were due to wear and tear. A remarkable record is that of a wrought-iron shaft which had worked night and day except on Sundays for twenty-seven years, during which period it had made about 340 million revolutions. Of these shafts 37 fractured in the journal necks, and 3 in the body. Of 41 cases of fractured connecting rods, 16 were due to the breaking of gibs or cotters, and 13 to the breaking of open-ended straps. Only one was due to an imperfect weld. 35 cases occurred of fractured cylinders and valve chests, 18 being of flat surfaces, such as doors and covers. 5 cylinders were broken by water in 4 cases feet were broken off, 35 breakages occurred in parallel motions, 28 governors and gears failed. Of 27 piston rods, 15 cases were those of fractures through cotter holes, 6 of cotters either breaking or becoming loosened. Of 27 piston rod crossheads, 15 were due to weakness or wear and tear; 22 pistons failed, 10 of which were due to cover bolts or junk rings getting loose or breaking, 3 resulted from the rings wearing thin and breaking. 21 links failed, most of which gave way at the bottom bend. 19 flywheels broke, 10 from the fracture of arms due to internal stress, bad fitting, &c.; 8 were due to cracks in the bosses, due to fatigue of the metal or by driving keys. 13 breakdowns occurred in air pumps and condensers, 12 in cranks, 11 of which were of cast iron; 12 gudgeons broke in beams, and 11 crank pins. The 6 beams which broke were all of cast iron.

Breaking Down Rolls.—The first set of rolls in a mill, by which the greater part of the roughing down is effected on the ingot, or billet.

Breaking Joint.—Has several significations. The longitudinal seams of boiler shells break joint, that is, are not placed in line, but alternate in order that each joint shall receive support from the solid plate in the ring adjacent. The joints in piston rings break joint instead of being placed in line with one another, which would permit some steam to pass by. The bricks in a loam mould are laid with their vertical joints alternating. Piles for fagoting wrought

iron have the layers with joints similarly arranged. The joints of steam and water pipes are said to be broken when they are separated for purposes of repair, &c.

Breaking of Metal.—Signifies the appearance of metal in the ladle, due to the ebullition of the hotter portions. The character of the striations, fine or coarse, and their slow or rapid movements indicate the hardness or softness of the iron, and its degree of heat, whether imperfectly or thoroughly melted.

Breaking Pieces.—Fittings inserted in connection with the spindles of rolling mills of less strength than the rolls, so that if the latter should be subjected to a dangerous overstrain the pieces will fracture before the rolls. A breaking spindle is a short spindle connecting the rolls with the pinions, and this breaks. A coupling box which forms the means of union may also break, with which intention one is often made of cast iron, the others being of steel. Sometimes again, when the top roll is not removable, a cast-iron breaking piece is placed on the top chock and this fractures if the top roll is pushed up too high.

A similar precaution is observed in many other machines, in which there is possibility of undue strain occurring. Forging machines of various kinds are often fitted with shearing bolts, which are of a strength calculated to shear before other vital portions of the machine should be broken by excessive pressure, which might be caused by work getting wrongly into the dies. Stonebreakers also often have a similar safety device. The parts are so designed in such cases that the replacement of the breaking piece wastes as little time as possible.

Breaking Strength. — The ultimate strength of a specimen piece or structure, corresponding with the stress at which it would fail by actual rupture.

Break Lathe.—A special type of heavy lathe, which has a magnified gap, formed by having a sole or base-plate upon which is carried an adjustable bed, with slide rest and poppet. This sliding movement allows of the gap being opened just as much as is necessary to admit work, so that a large wheel, or bed-plate may be swung on the face-plate, and the poppet and rests brought up close for turning, boring, and facing. The work may be held on the plate alone, or partly supported by the poppet—as in the case of a flywheel with shaft inserted. Auxiliary rests are also fitted, standing on the base-plate, so that in the most complete type, three sets of tools can be brought into operation. A good example is illustrated in Fig. 57; by James Spencer & Co., of 24-in. centres, admitting 10 ft. diameter in the break, by 8 ft. in width. The greatest distance between centres, with break open, is 10 ft. 4 in. The face-plate (the slots of which are not shown) is 7 ft. 6 in. diameter.

There is one rest on the slide-bed, and two on the base, mounted on pillars. A self-acting feed is imparted to either of these from an overhead rocking-shaft, actuated by a connecting-rod from the slotted disc seen at the rear of the headstock. The poppet is movable along its bed by a worm and wheel, the latter driving a pinion gearing with a rack on the inside edge of the bed; a similar fitting is provided to the slide-rest, the square handles of the worm being either worked by hand, or power ratchet. The headstock is fitted for single gear, driving direct with the belt cones A; double gear, employing the usual back gear, B, C, D, E; or treble, employing the extra train seen, F, G, H, the last gearing with the internal spur wheel cast with the face-plate. The entire shaft, carrying with it wheel G and pinion H, is disengaged by sliding it endwise, through the handwheel J, screwing the clutch-fork endwise.

Breakwater.—A structure built in the sea to break the force of the waves. It may be an isolated structure, or a continuation of a pier, or a mole extending seawards. Of these structures there is more below the water than appears above.

The oldest method of building, is that of tipping vast quantities of broken stone into the sea, until it begins to rise above high water. When a pile of rubble is thrown down anywhere at random the loose stones all arrange themselves in a natural slope. Thus the width at the bottom of a heap becomes much greater than that at the top, resulting in stability, and if there were no terrific storms the natural slope of the stones in a breakwater would afford protection against the billows. But all breakwaters built thus suffer in winter time, because

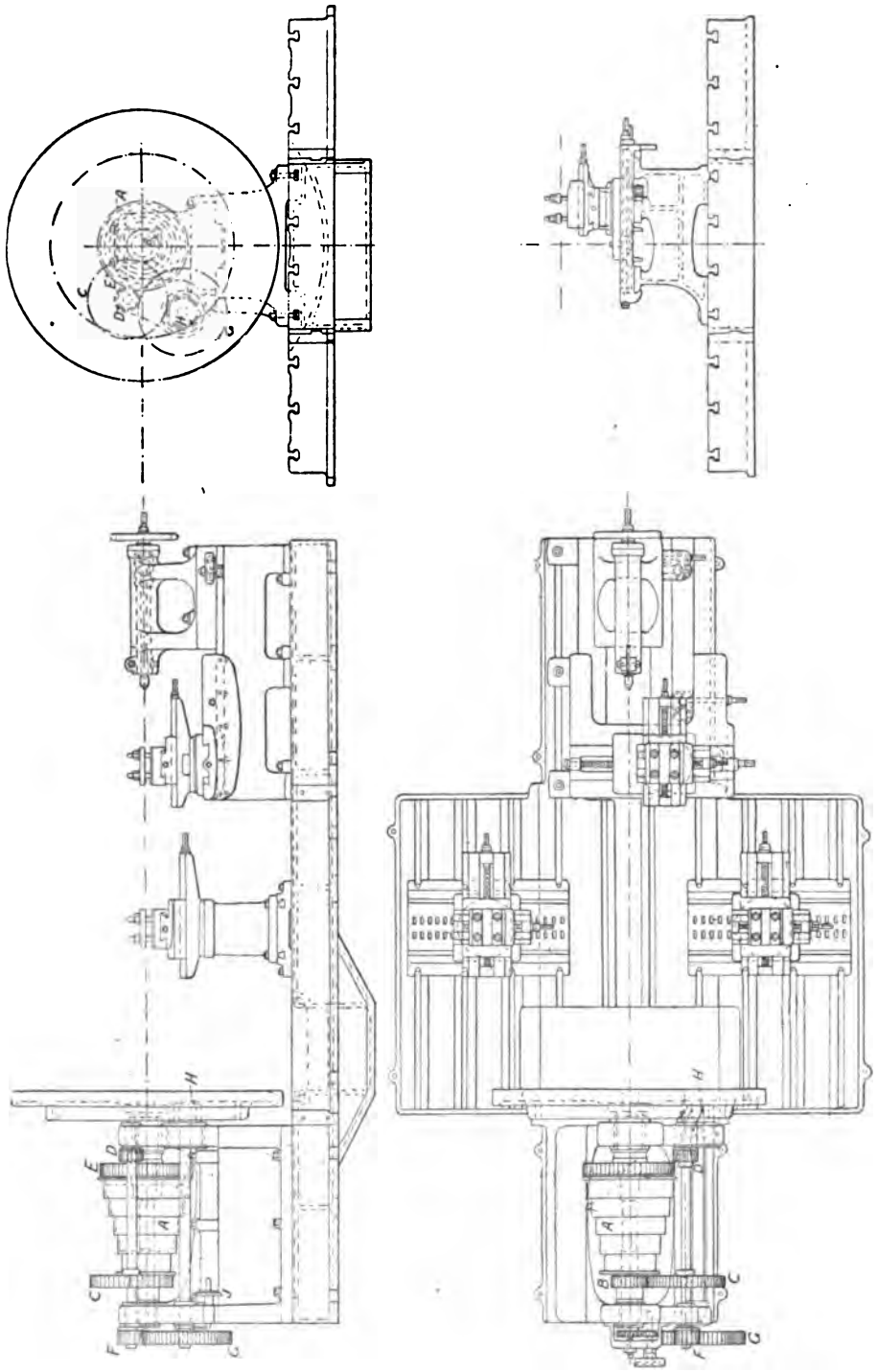


Fig. 57.—Break Lathe.

they are liable to be damaged by heavy storms, and so are constantly in need of repair.

The modern way of building, is to employ the assistance of divers who go down and lay concrete in a regular way. In some of these works hundreds of thousands of pounds sterling have been sunk judiciously by patriotic governments, money which could not have been expended in a way more conducive to national interests. But the breakwaters which defy the league-long billows are only the capstones of the buried work beneath, often but one-tenth or one-twentieth of that which is not seen.

The breakwater now being built at Peterhead has been extending out into the North Sea at the rate of over 100 feet in a year since 1893. Its estimated cost was about a million sterling. From 150 to 200 convicts are employed on this,

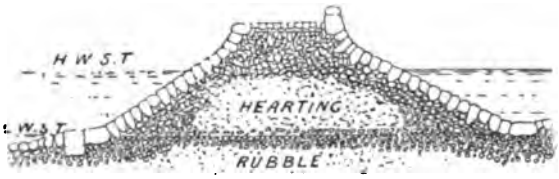


Fig. 58.—Tyne Piers, 3,400 feet from commencement.

with about thirty warders, and a large proportion of freemen. A Titan capable of lifting 50 tons, and which cost £15,000, carries and deposits the concrete blocks.

How conditions affect the construction of a breakwater was well put by the late Mr Messent in speaking of his own great work, the breakwaters at the mouth of the Tyne, Figs. 58, 59. The first 1,500 feet of the North Pier took it out to a depth of 18 ft. or 19 ft. below low water, and so far it was an easy piece of construction, which was carried on at a good rate, 300 feet in a year, and sometimes more. It was thought a cheap work, costing less than £60 per lineal foot. Going out 300 feet further the structure was built twice as strong as the first 1,500 feet, and that did not prove strong enough, three times the strength not being sufficient. The work was practically a monolith of concrete from the rubble base, beginning at 20 ft. to 28 ft. below low water, with a facing of concrete blocks, and those blocks still further faced with stone, in order to resist the friction of the rubble stones driven along by the sea.

To show how conditions, chiefly of depth of water, affect expense, the cost per lineal foot of some notable breakwaters was as follows:—Alderney, £190 (120 feet below low water); Portland, £120 (45 feet deep); Dover, £360 (a landing pier, and covered with granite ashlar); Holyhead, £160; Plymouth, £300; Marseilles, £210; Algiers, £122; Cherbourg, £219; Newhaven, £58. 10s. (only from 12 feet to 15 feet below low water); Manora, £62. 5s.

The construction of breakwaters using concrete often includes a foundation of **Bag Work**. Or the outer wall may be built of concrete blocks, with a hearting between. In some examples

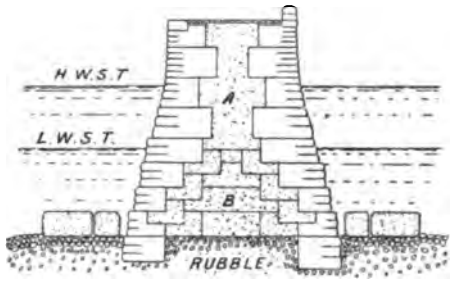


Fig. 59.—Tyne Piers, 4,900 feet from commencement.

A. Portland Cement Concrete Hearting. *B.* Concrete Blocks.

monolithic work has been adopted. The sections Figs. 58, 59 illustrate some of the most important points in construction.

Breast Hole.—The hole, arched in form, through which the fire in a cupola furnace is lit, and through which the cinders are drawn. It is closed by a *breast plate* of sheet iron, luted with clay while the blow is on.

Breast-Slide Planer.—*See* **Armour Plates—Planing Machines for.**

Breast Wheel.—*See* **Water Wheels.**

Breathing, Breathing Space.—Denotes the act of expansion, and provision for the same made in portions of the end plates of horizontal boilers, and in some degree in the crown plates of vertical boilers. It signifies that unless provision is made for the elastic movements of these plates when subjected to heat and varying pressures, trouble will be caused by grooving and furrowing. A plate that is not left free to yield will throw strain on the parts adjacent, which will result in the evils just named. In the

attempt to support plates weak in themselves by ample staying, the opposite evil, that of too great rigidity, has often resulted. In good practice therefore a minimum distance must be left free to breathe between the furnace flange and the terminations of the gusset stays, or of the tubes in tubular boilers. This is generally fixed at 9 in. or 10 in. and the space so left is the breathing space.

Breeches Flued Boiler.—A Lancashire

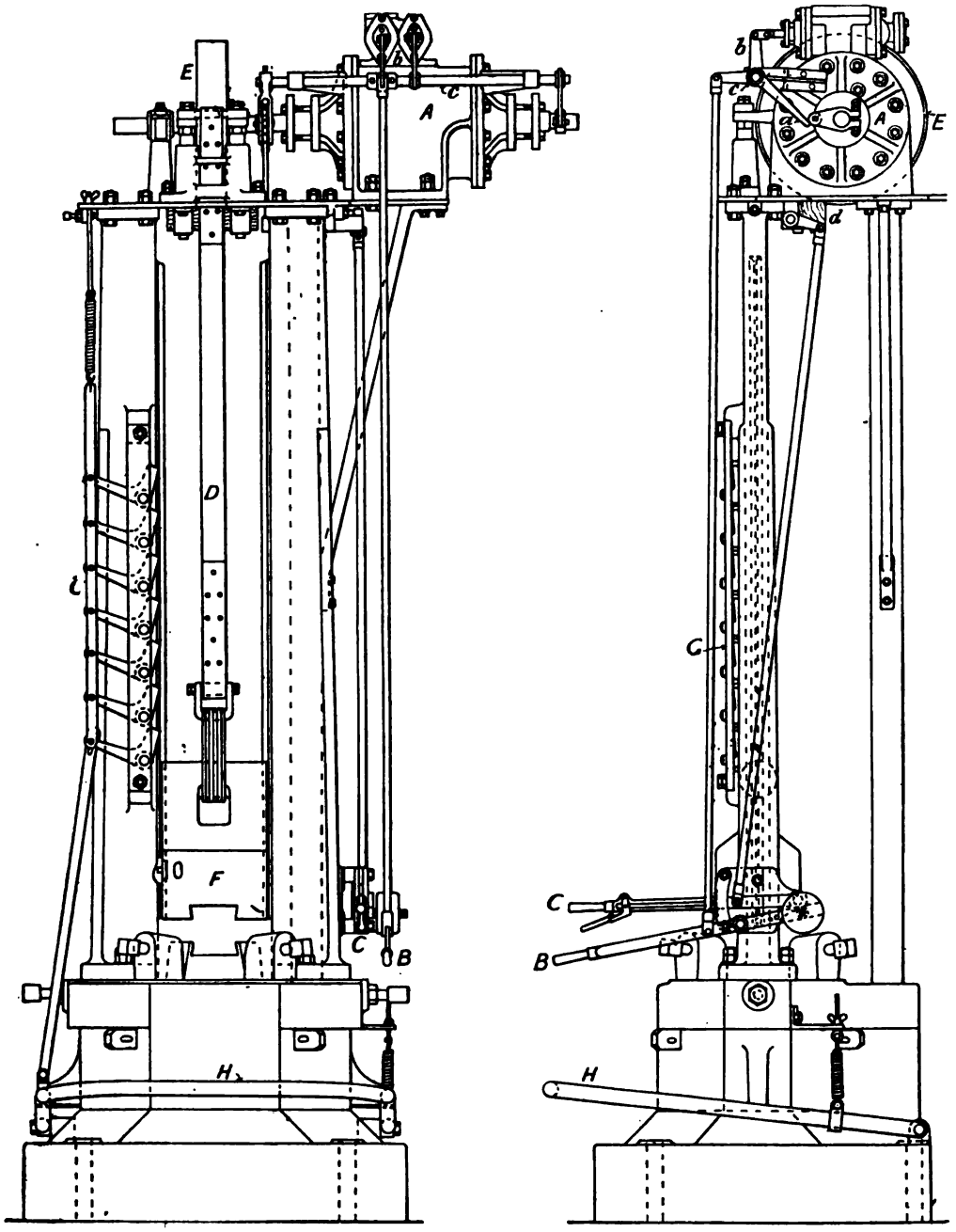


Fig. 60.—Brett Lifters applied to Drop Hammer.



Fig. 62.—Battery of Forging Stamps, with Brett Lifters.



Fig. 63.—Arch Suspension Bridge.

To face page 72.

boiler in which the two furnace flues unite in one large flue just beyond the fire bridge. The object is to provide a large combustion chamber, and reduce smoke. The large flue is strengthened with conical tubes, which also assist the circulation. The weak part of the breeches flued boiler is the "breech" which connects the furnaces with the flue, and this has to be stayed. The **Galloway Boiler** is not strictly a breeches flued type, for the hinder chamber is wide, and of elliptical shape, except where it joins the hinder plate. It has conical tubes.

Breeches Pipe. — A pipe having two branches divergent, or parallel, bifurcating from a single one.

Brett Lifters.—The automatic lifters of Mr Brett, applied primarily to self-contained drop hammers, but to batteries of stamps as well. The design is that of a lifting apparatus separate from the foundation, in order that the jar of the blows shall not be transmitted to the lifting mechanism. A wing piston in a cylinder, actuated by steam or compressed air, lifts a couple of levers by which the hammer is raised. A loose pulley that runs between the levers sustains the weight of the hammer during the act of lifting, but it runs loosely when the hammer descends. The cylinder is seen at A, in Figs. 60, 61 (in section in Fig. 61), and a photograph of a battery of hammers in Fig. 62, Plate V. The action of the valve B is controlled by the valve C, of piston type, the steam entering the passage *a*, and exhausting through *b*. The height of lift given to the valve regulates the amount of steam admitted to the cylinder, and this is controlled by the attendant operating the hand lever B, Fig. 60, and yoke *b* on a rockshaft *c*. As the height of lift given to the piston valve controls the amount of steam admitted, it also limits the distance through which the wing piston rotates until arrested by the stop block D, Fig. 61, and until the lifting levers keyed on the shaft are arrested by the buffer blocks seen immediately below *c*; *a*, Fig. 60, regulates the valve automatically. The position in which the valve is shown in Fig. 61 is that of open to steam from the inlet, the steam passing round the valve to enter *a*, to the lower face of the wing valve. When the steam exhausts, the wing valve returns to its first position in readiness for the next lift. In Fig. 60 D is the belt passing over the pulley E.

The advantage of the levers is their elasticity, which lessens vibration. They are clamped at one end on the shaft, and connected by a link at the other, around which the lifting belt is looped.

The self-contained character of the lifters permits them to be so independent that they can be fixed to a beam supported in any manner, and over the hammers, or away from them, and on the ground. Power can be brought by any steam or air pipes.

There are several variations in this design. One of the most valuable is that in which provision is made for effecting variations in the height of the blows. The operating lever C fits in notches in a quadrant plate, and regulates the amount of opening of the valve by hand, *d* being a connecting lever. Seven stops G are provided, in either one of which the tup can be held when desired.

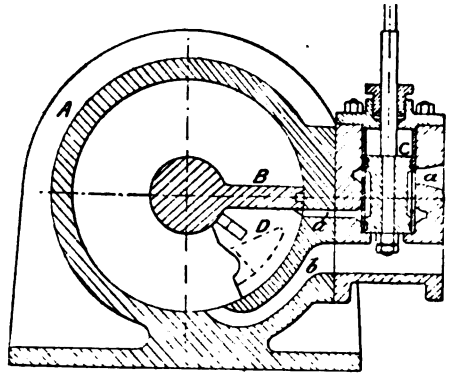


Fig. 61.—Section through Cylinder and Valve of Brett Lifter.

Brewing Machinery.—The art of brewing consists in the preparation of an aqueous solution containing some sugar, some that has been converted into alcohol and carbonic acid, and the tannin, and resinous properties contained in hops in a palatable form. It is not necessary that beer shall be brewed from malt. Other grains contain starch, which may be converted into sugar by the action of sulphuric acid, and can be used wholly, or in part, with the hops, in the same way that the solution made from the malt is. In fact a large portion of the beer that is

drunk, both in this country and America, and on the Continent of Europe, is made largely from glucose prepared from other substances than malt.

Malt is barley which has undergone a process of steeping and heating, that alters its nature, in the direction of the conversion of the starch contained in the barley into glucose. Machinery is required at every step of the process. The barley, in the process of cutting and in its progress to the malt house, picks up a good deal of dust, dirt, and foreign bodies, such as pieces of iron, all of which have to be extracted before it is malted. Hoists, elevators, and conveyors are required at almost every step. The barley arrives at the malt house in sacks, and is hoisted up to the top floor usually, in order that it may fall by gravity through the different apparatus used in cleaning it. Elevators are often used for the purpose. The hoist employed is a very simple affair, merely a drum, on which a rope is wound, connected to some source of power, so that the drum can be thrown into gear by pulling a rope on either floor, and thrown out by releasing the rope. The elevators employed are of the usual type, consisting of buckets attached to chains passing over pulleys, the buckets either filling automatically by dipping into the grain to be moved, or being filled by hand, and emptying themselves into hoppers, or on to screens, by falling over in the usual way. Conveyors are sometimes of the same type, or are merely belts running horizontally, the grain adhering to the belts by friction, and being turned down shoots, or into hoppers, by the diversion of the course of the belts with jockey pulleys. For moving grain in large quantities, an exhaust fan is sometimes employed, in conjunction with a suction member shaped like an elephant's trunk, the grain being sucked up into the trunk, and delivered at the floor required by the operation of the exhaust.

Barley Cleaning Machinery.—This consists of a number of revolving wire and metal screens, on to which the grain to be cleaned is passed by gravity. The screens are of different meshes, and the foreign substances are gradually ejected, while the grain itself is sorted out into sizes, passing to different hoppers. In conjunction with the screens there are air and water apparatus, designed to extract the dust. Either air or water is forced through the grain, at a certain part of its travel, carrying the dust out with it to the atmosphere, or to a filter arranged to receive it. Iron and steel are extracted by passing the grain through a magnetic separator, consisting of a barrel containing several steel magnets, to which the pieces of iron adhere, as the grain passes through.

Preparing the Barley for the Mash Tun.—The mash tun is the large vat in which the barley is boiled to extract its sugar. Before it is allowed to enter the mash tun, after it has been cleaned, the barley, made into malt by being first steeped in water, and then dried on special floors arranged for the purpose, the malt being repeatedly turned during the process, is then exposed to the heat from anthracite coal in a kiln. Here the grain approaches a certain stage of germination, when it is carried to the crusher; or after steeping, it is enclosed in a revolving drum, through which warm moist air is continually passed. The latter process, which is known as the pneumatic, is claimed to lessen the time required very considerably, and to reduce the labour cost. The principle is the same in the two methods, heat and moisture are required to enable the grain to commence germination, while the gases formed during the process must be carried away. From the kiln, or the pneumatic drum, the grain passes to the crusher, consisting of a pair of steel drums, between which the grain passes, the object being to enable the water in the mash tun to more easily dissolve out the sugar contained in the malt, the starch now having been converted into sugar.

At the Mash Tun and Copper Boiler.—The mash tun is the vessel in which the sugar is dissolved out of the malt. The crushed malt is fed into it, usually from above, sometimes through a mixer, consisting of a cylinder with radial arms arranged on a shaft passing longitudinally through it. The crushed malt is fed into the cylinder, and is there mixed with water, thence passing on to the mash tun. In some cases the mixing is done in this vessel by means of revolving radial arms. Over the mash tun is an apparatus known as a sparge. It consists of two or more copper pipes con-

nected to a centre, and arranged to revolve around it, there being sometimes at the centre a vessel forming a reservoir. The office of the sparge is to deliver water, "liquor" as brewers call it, hot or cold, to the contents of the mash tun equally, and to accomplish this there are a number of fine holes in the pipes forming the radial arms. Water issues from these holes in a fine spray, and the force of the issuing jets causes the sparge to move round its centre, so that the spray is constantly meeting a different surface of the liquor in the mash tun. It is also found necessary in some cases to keep the liquor in the mash tun in motion while the solution is proceeding, and this is accomplished partly by the mixers referred to above, and partly by raising the lower portion of the liquor to the top, the liquor above then falling by gravity. In some cases a pump removes a portion of the liquor from the bottom, and forces it through a vessel in which a steam coil is placed, whence it passes to the top of the mash tun, in others the bottom liquor is forced up and heated by a jet of steam. The water in the mash tun which is dissolving the sugar from the malt is hot, and it is usually heated by steam passing in a coil of pipe in the tun. In the early days of the use of steam for heating, a steam jet was employed, going straight into the liquor, but as steam sometimes contains grease, when it has been passed through a condenser, this method was abandoned, though, as is well known, it is more efficient. The hot solution of sugar is carried from the mash tun to the copper, where the hops are added, and where it is kept boiling for a certain time, and is then drawn off and cooled, before passing to the fermenting tun. The copper boilers are sometimes heated by fire underneath, and sometimes by steam in pipes inside.

Cooling and Fermenting.—The wort, as the liquor consisting of a solution of sugar and hops is called, is run off first into a vessel called a hop back, in the neighbourhood of the boiler, and is then pumped up to a large shallow tank in the upper floor, where it is allowed to cool partially by evaporation. It is then passed over, or through a refrigerator. The brewery refrigerator is very like a milk cooler. It consists usually of a vessel standing vertically, and presenting on both sides corrugated metal surfaces. In the space between the corrugations on the inside, water or cold brine is circulated, and the wort to be cooled passes down outside over the corrugations, the cooling being effected partly by conduction to the circulating water, and partly by evaporation from the wort itself. From the refrigerator, the wort passes to the fermenting tun, where the yeast is added, and where the final operation, the splitting up of the sugar into alcohol and carbonic acid, takes place. There are skimming apparatus used in the fermenting tuns, to remove some of the superabundant yeast that is formed; they consist sometimes of an inverted metal cone connected to a copper pipe passing to the bottom of the tun, and sometimes of a trough with a tube attached, and with arms revolving on the surface, sweeping the yeast into the trough. The entrance to the tube is under control from the side of the tun. The fermenting tun is also fitted with what is called an attemperator, a coil of pipe, fixed in the tun, which can be used for steam, hot water, or cold water, according as the fermenting requires to be accelerated, or retarded. From the fermenting tun, the beer passes to the large vats, or the casks, where the process is completed.

Machinery Required Generally.—All breweries must have boilers for the production of steam, for heating and for driving pumps, and engines that work different apparatus. For the economical generation of steam also, the condensed steam should all be brought back to the boiler, and where the plant is large, the steam used by the engines should also be condensed, and brought back. In fact, nearly all the methods for economical generation of steam for other purposes, are applicable to breweries. In addition, many breweries have their own wells, from which the water is pumped; many also combine a bottling business with brewing, in which case bottling machines, and apparatus for rapid cooling, and carbonising are often added, the apparatus consisting of a vessel through which the beer passes, in which it is exposed to the cooling action of cold brine, and later to the action of a jet of carbonic acid gas.

Filters are also necessary, corking machines, bottle, and cask-washing machines, &c. For large breweries, especially where a large stock is held, a refrigerating plant is useful, as it enables any part of the building to be maintained at any desired temperature, even in the hottest weather. Many breweries also run their own electric light plant, and take power from it for working different machines. Many also make their own casks.

Brick Arch.—The arch in a locomotive boiler furnace which directs the flames backwards in order to delay their passage into the tubes.

Brick Flues.—The smoke flues of horizontal land boilers, to distinguish them from the furnace flues.

Bricking up.—The building up of the body of a loam mould or core with bricks.

Brick-making Machinery.—The two main types of brick-making machines, the dry or semi-plastic, and the plastic, produce the bricks respectively by pressing in moulds, and forcing through a die. In the first case the moulds finish each brick to size, in the second a long piece is made, and subsequently divided into separate bricks by a cutting table, having a row of vertical wires, like a frame saw. The dry method involves a mixer, for the clay, a pug-mill, from which the moulds are charged. The latter are carried for convenience on a circular revolving table, and as a mould is filled, it is raised up, and placed under the press, to be squeezed into finished shape. The only other operation is that of drying. The dies are lined with case-hardened steel for durability, and are removable when worn. In the plastic type of machine crushing rollers are employed, passing the clay to the pug-mill, where it goes through the die (which is lubricated to facilitate the forcing) and on to rollers leading to the cutting table. Separators are sometimes fitted, in the form of jaws or pallets, which grip the cut bricks, and draw them slightly apart, so that they can be loaded on to drying cars without being touched by hand.

Bricks which require an extra finish, as when used for facing purposes, are afterwards treated in presses, having cast-steel dies which impart a fine surface, either plain, or ornamental. To prevent the top die sticking to the work, it is heated by steam, through pipes. These presses are driven from an overhead shaft by eccentric and lever, and the sliding die-holder works between adjustable guides, to ensure proper register.

Bricks.—These are used in engineering to a large extent, chiefly the various fire-bricks for melting furnaces, flues of boilers, and for core stoves. Some are of a special character to withstand the corroding action of different kinds of ores, fluxes, and metals. Common bricks are used for loam moulds.

Bridge.—Bridges are structures erected to carry roads, railways and waterways across streams, roads and valleys. They may be of one span or several. Bridges of many spans, each comparatively short, are known as *viaducts;* such being generally used as a cheaper alternative to a long and high embankment. An *aqueduct* is of similar construction, but is arranged to carry a waterway. The *substructure* of a bridge consists of the abutments or end-supports, and the piers or intermediate supports, if any, together with their foundations. The rest of the bridge is the *superstructure* or upper part, and comprises the girders, or arches, or chains (according to the type) and the roadway or platform, and parapet.

The Arched Bridge.—The utility of the arched bridge from the engineer's point of view is much less than formerly, in consequence of its almost entire supersession by the lattice girder types. The early engineers made many arched bridges of masonry, followed by those of timber and of cast iron. These last are rarely constructed now, so that the following remarks relate to a period which has passed away, but many fine examples of which remain, though numbers have been dismantled within the recollection of the present generation.

The old cast-iron arched bridges have not often been removed on account of decay, but because they were originally designed for lighter traffic than that of the present. Many that remain are sound after three or four generations.

The problems of stability in an arch of masonry and one of cast iron are not identical. The theoretical stability of an arch of stone depends on the non-turning of the stones or voussoirs composing it over one another. But in

actual fact stability to a great extent is a question of the friction between the voussoirs, or the excellence or otherwise of the cementing material used. This last is considered to improve with time for a long period, after which deterioration begins to set in. Besides this, the mortar and the workmanship are not alike in all parts of the structure. But no such problems arise in arches built of cast iron. In the first place the equivalents of voussoirs have been used but seldom, and they are not cemented, but held by other means. But the greatest difference lies in the expansion which takes place in iron, producing stresses and strains which are negligible in arches of masonry. Another of nearly equal importance is that the stone arch is not deflected by bending moments, but is a practically rigid structure, so long as the voussoirs do not slide, or the materials become crushed. But an iron bridge becomes deformed by its loads, which with temperature effects may produce serious changes in the conditions of stability.

Cast-iron arches are mostly made of long ribs bolted together. But there are one or two interesting examples of transitional forms in which the masonry design is retained in the simple substitution of voussoirs of iron for those of stone, before the rib design was introduced. One of these was erected over the River Wear at Sunderland about 1795. Its span is 236 ft. and its voussoirs are 5 ft. in depth by 2 ft. in length. There is another at Solferino having a central span of 130 ft. in which the voussoirs are hollow castings, but solid in side spans. One of the proposals for the Menai Bridge was for voussoir arches.

The rib type of arch is of early date, one of the best examples being the present Southwark Bridge, which has the largest span of any cast-iron bridge in the world. The most curious feature, however, of this design is that Rennie seems to have had the arched timber bridge in his mind, inasmuch as the ribs are deep and thin segments of cast iron, resembling the timber arches of the bridges that were once built. A similar example occurs in a bridge over the Wye at Chepstow, which has five arches of cast-iron ribs without flanges.

Only gradually did the flanged rib come in, and then the influence of the ideas of that period with regard to the difference in area of top and bottom was evident. The old belief that the proportions between the ribs should be about equal to the differences of cast iron in tension and compression wrought mischief, because it took no account of the weakening influences of internal stresses due to unequal cooling, with consequent inconvenient camber. Later the flanges were made equal or nearly so in section. These arches differed from the true voussoir arches only in the greater lengths of the ribs, and the substitution of thin but flanged webs for the thick hollow cast voussoirs.

But the arch has not disappeared from engineering practice with the abandonment of cast iron. Several examples of steel arched types exist. In some of the early wrought-iron bridges of this design the influence of the timber arch is conspicuous, inasmuch as the wrought-iron plates are bent and laid over one another just as the timbers in the arched wooden bridges were done. These arches are all destitute of bracing, but there is a sub-type in which assistance is derived from bracing. Fig. 63, Plate V., is an arch suspension bridge at Bedford.

In this article attention will be directed chiefly to the determination of the stresses in certain types of bridge superstructures, as a necessary preliminary to their design. Reference should be made to the article on **Beam** for the method of estimating reactions, bending moments, shearing forces, deflections, and moments of resistance of beams variously loaded and supported.

Determination of Load.—The total load to be sustained by a bridge structure consists of many parts or forces, namely:—

(1.) A constant gravity load, due to the weight of the superstructure itself.

(2.) A variable gravity load, due to the weight of trains, vehicles, passengers, and other moving bodies passing over the bridge, as well as to occasional accumulations of snow.

(3.) A variable lateral load, due to the pressure of gusts of wind on the exposed surfaces of the superstructure and bodies upon it. This may occasionally amount to as much as 60 lb. per square foot of normal surface.

(4.) A variable longitudinal force, due to the

rapid acceleration and retardation of a heavy train, coupled with frictional and wind resistance.

(5.) A variable vertical force, due to the rapid rotation of unbalanced masses moving over it.

(6.) In the case of a *curved* railway bridge there is also a lateral load due to the centrifugal force of a rapidly moving train, arising from the resistance of heavy bodies to radial acceleration.

Thus, to take an extreme case, a train weighing 300 tons, moving at 60 miles an hour (88 feet per second) round a curve of 1,000-feet radius, would exert a total lateral pressure against the rails of 72·6 tons; for

$$F = \frac{Wv^2}{gr} = \frac{300 \times 88^2}{32 \times 1{,}000} = 72{\cdot}6.$$

In designing bridges all these forces should be taken into account as far as possible; but in this article space does not allow of more than a brief consideration of the effect of structural load and of moving loads in producing stresses.

In the case of a *public road bridge* it is usual to allow for a distributed load of 1 cwt. per square foot, this being rather more than the weight of a very dense crowd of people. A point which should not be overlooked is that a bridge might possibly carry a crowd uniformly distributed over its length, and yet fail when the crowd covered a portion only of its surface. Hence for safety all possible distributions of the crowd must be provided for. Further, during the passage of a traction engine or a road roller, there will be a rolling load of about 10 tons per wheel.

In the case of a *railway bridge*, the maximum moving load on each line of rails is a string of heavy locomotives, and the bridge must be capable of bearing this weight when distributed in any manner. According to Unwin, we may take the rolling load for each line of way at 2 tons per foot for spans of 25 feet, at $1\frac{3}{4}$ ton for spans of 30 feet, at $1\frac{1}{2}$ ton for spans of 40 feet, and at $1\frac{1}{4}$ ton per foot for spans of 60 feet. The load on a pair of locomotive driving wheels may be as much as 34 tons.

Structural Weight of Bridges.—The total weight of a railway bridge superstructure is the sum of the weights of its component parts, namely:—

(1.) The platform covering, including the permanent way.

(2.) The girders carrying the platform, comprising the cross girders and the longitudinal bearers under each rail.

(3.) The horizontal bracing needed to ensure the lateral stability of the platform.

(4.) The main girders, or equivalent parts.

In the case of a double line of railway bridge of ordinary span, the weight of the platform girders (according to Baker) is about 7 cwt. per foot run of the bridge, and that of the horizontal bracing is about three-fifths of this, or, say, $4\frac{1}{4}$ cwt. per foot. Also the gross "useful" load to be carried by the main girders of a bridge is approximately expressed by the relation

$$w = 40 + x\sqrt{S},$$

where w cwt. per foot run is the so-called "useful load," or structural weight excluding main girders; S feet is the span, and x is a coefficient varying in value from about ·4 to ·6 according to the type of bridge, when built of steel.

It is a great convenience to be able to express the weight of any girder in terms of the load it will carry. This can be done approximately by means of a simple formula proposed many years ago by Professor Unwin in his "Wrought-Iron Bridges and Roofs."

Let W tons = total external distributed load over the clear span of a girder.
G tons = weight of girder itself over the clear span.
S feet = clear span.
d feet = effective depth of girder.
f tons per square inch = average stress on the section of the flanges at centre of span.
r = ratio of span to depth.

Then

$$G = \frac{WS^2}{Cdf - S^2} = \frac{WSr}{Cf - Sr}.$$

For small wrought-iron *plate* girders C is about 1,400.

For example, if the span is 50 feet, the load

per foot 1 ton, the ratio of span to depth 12, and the stress allowed 5 tons per square inch, then

$$G = \frac{50 \text{ tons} \times 50 \text{ ft.} \times 12}{1{,}400 \times 5 \text{ tons per sq. in.} - 50 \text{ ft.} \times 12}$$
$$= \frac{2{,}500 \times 12}{7{,}000 - 600} = 4{\cdot}7 \text{ tons.}$$

The ratio of the weight of a bridge girder to the load it will carry depends on the type of girder and on the span. For each type of superstructure there is a limiting span, beyond which the bridge would not carry its own weight. The question of the theoretical weight of bridges has been investigated by Sir B. Baker in his "Long Span Railway Bridges." Some of the forms of bridges he examined were:—

sions arrived at by Baker in reference to six types of *steel* bridges:—

Type.	Ratio of Weight of Superstructure to Load for various Spans.				
	300 ft	600 ft.	900 ft.	1,200 ft.	1,500 ft.
Lattice -	·35	1·35	10·6	...	...
Bowstring	·31	·89	2·25	8	..
Cantilever	·23	·61	1·27	2·6	5·35
Arched -	·27	·69	1·35	2·66	5·5
Suspension	·23	·6	1·22	2·38	5
Continuous	·23	·61	1·15	1·7	2·37

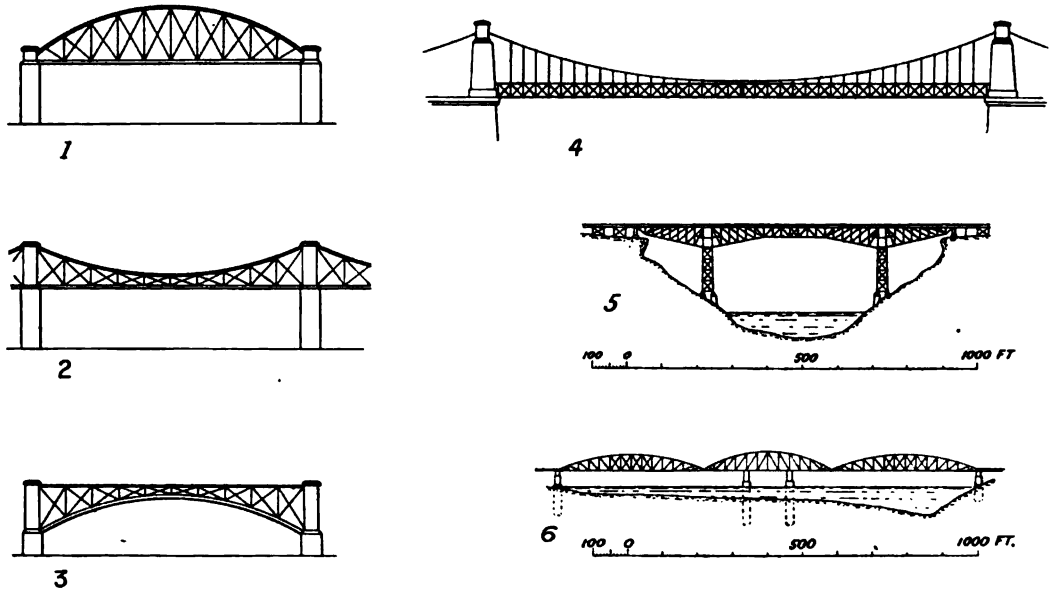


Fig. 64.—Some Bridge Types.

The lattice girder type, with parallel flanges.

The bowstring girder type (Fig. 64, 1).

The cantilever lattice type, of varying depth (Fig. 64, 2).

The arched rib type, with braced spandrils (Fig. 64, 3).

The suspension bridge, with stiffening girder (Fig. 64, 4).

The continuous girder bridge, of varying depth, two examples of which are given in Fig. 64, 5 and 6.

The table in next column gives some conclu-

Thus for example a parallel lattice girder bridge of 900 feet span weighs 10·6 times as much as the uniform load it will carry, while a bowstring girder bridge of the same span weighs only 2¼ times the load it will carry; thus showing the superior economy of the bowstring girder over the lattice for long spans. For the comparatively short span of 300 feet, however, the advantage of the bowstring girder is much less marked.

The results of the investigations for the above types of bridges are shown graphically in Fig. 65,

where a curve has been drawn for each type. Horizontals represent *spans* in feet, and verticals represent the gross *weight* of steel superstructure in cwts. per foot of span for a double line bridge. These valuable curves show at a glance the

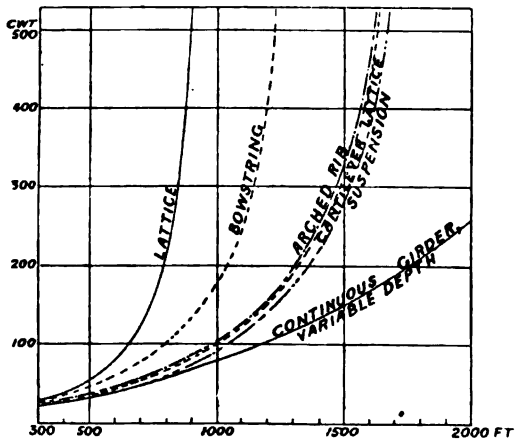


Fig. 65.—Ratios of Weights of Bridge Superstructures to loads for various spans.

comparative economic values of the respective systems as regards the *superstructure* of the main span. They do not represent, however, the comparative costs of complete bridges, for which no general rule can be given; as some types of bridges require more expensive piers than others.

Determination of Stresses on Bridge Girders.—The graphical method of determining the stresses in braced girders here described is an application of the well-known elementary statical theorems of the triangle and polygon of forces. For convenience it is assumed, as a sufficiently close approximation to the actual conditions, that the several bars or members of the girders are connected by frictionless pins.

The upper drawing in Fig. 66 is the "frame" diagram of a Warren girder of 50 feet span, made up of five 10 feet bays, and forming one of a pair of girders carrying a double line of railway. The weight of one girder and half of the platform is taken as 1 ton per lineal foot of span. This is the *dead* load. There is also a *travelling* load of $1\frac{1}{2}$ ton per foot run, which will be afterwards considered and combined with the dead load. The joints of the lower boom or chord, at each of which is a cross girder, carry the entire load.

After transferring the distributed load to the joints, letter the frame diagram as shown in Fig. 66 (Bow's system of lettering or notation being used) by placing a capital letter between the line of action of each two external forces and also in each triangular space. Then the bar joining the pins marked 1 and 2 is called the bar SH or HS; and so on for the rest.

To construct the stress or force diagram, shown immediately below the frame diagram in Fig. 66, choose a convenient scale, and set off the line of loads *a b c d e f g*. The upward reactions are then represented by the lines *gh* and *ha*. Beginning at a joint where only *three* bars meet, as that marked 1, draw a line through *b* parallel to BS, and another through *h* parallel to SH, these intersecting at *s*. Then *bs* represents the stress on the first bay of the lower boom, and *sh* that on the first diagonal bracing bar. The arrows show that BS is a tie, since it *pulls* from the joint, and that SH is a strut, since it *pushes* on the pin.

Passing next to the joint marked 2, draw

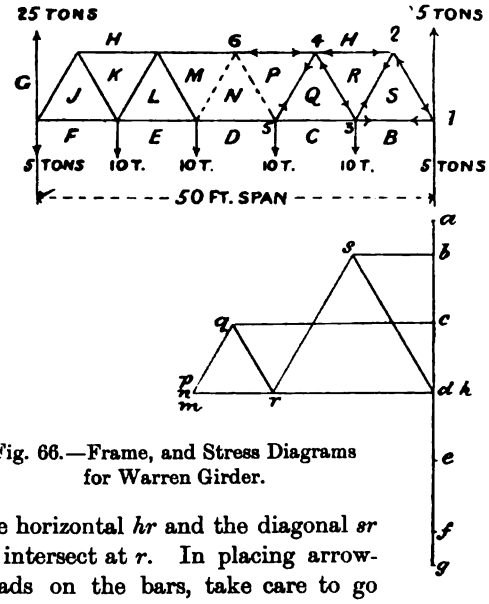


Fig. 66.—Frame, and Stress Diagrams for Warren Girder.

the horizontal *hr* and the diagonal *sr* to intersect at *r*. In placing arrow-heads on the bars, take care to go round the joint in the watch-hand direction, and round the triangle of forces in the direction *srh*. We thus find that RH is a strut and SR a tie.

Turning our attention now to the joint marked

3, we place opposing arrows on the bars already dealt with, and then complete the polygon of forces *bcqrs*; which represents, in magnitude and direction, all the forces acting at the point in question. In the same way all the remaining joints might be dealt with; but, since the loading is symmetrical, it is sufficient to draw one-half of the complete diagram of forces, the other being similar.

The magnitude and nature of the stresses on the several members of the girder are best set forth in the form of a table, in which a tensile stress is indicated by a *minus* sign, while a

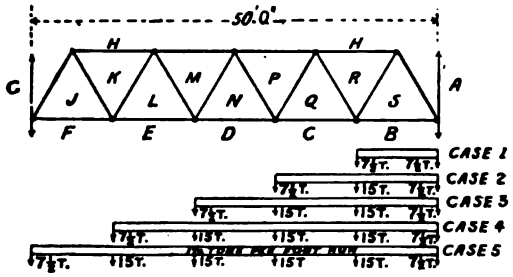


Fig. 67.—Stress Diagram.

compressive stress is denoted by a *plus* sign or by the absence of any sign whatever, thus:—

	Bar.	Stress.
		Tons.
Upper Boom	RH	23
	PH	34·6
Lower Boom	BS	−11·5
	CQ	−28·8
	DN	−34·7
Diagonals	HS	23
	SR	−23
	RQ	11·6
	QP	−11·6
	PN	0

Observe that the thrust on the upper boom and the pull on the lower boom increase from the ends of the girder to the middle, while the stress on the diagonals *diminishes* from the ends to the middle. In fact, a uniform statical load produces no stress at all on the two middle diagonals.

Next consider the *travelling* load. Referring to the force diagram in Fig. 66, as the load of 1½ ton per foot run travels from the right-hand end of the girder to the other, it will

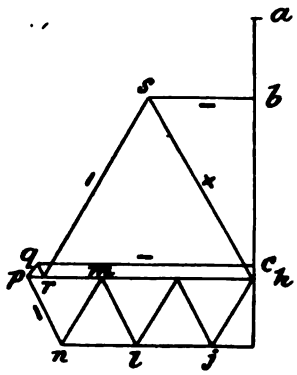


Fig. 68.
Stress Diagram. Case 1.

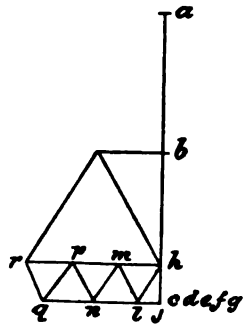


Fig. 69.
Stress Diagram. Case 2.

successively occupy the positions shown in cases 1. to 5. Fig. 67. Stress diagrams have been drawn corresponding to each of these positions, Figs. 68-72, and from them have been deduced the values and signs of the stresses, tabulated below for four cases:—

	Bar.	Stress in tons due to Live Load.			
		Case 2.	Case 3.	Case 4.	Case 5.
Upper Boom (in compression)	RH	19·3	28·	32·8	34·5
	PH	20·9	38·5	48·2	52
	MH	13·8	31·5	46·5	52
	KH	7	15·7	27·5	34·5
Lower Boom (in tension)	BS	−9·6	−14	−16	−17·4
	CQ	−20	−38·5	−40·5	−43·5
	DN	−17·4	−35	−47·5	−52
	EL	−10·5	−23·5	−37	−43
	FJ	−13·5	−7·5	−14	−17·4
Diagonals	HS	19.3	28	32·8	34·5
	SR	−19·3	−28	−32·8	−34·5
	RQ	1·6	10·4	15·4	17·5
	QP	−1·6	−10·4	−15·4	−17·5
	PN	−7	−7	−1·6	0
	NM	7	7	1·6	0
	ML	−7	−15·7	−19	−17·5
	LK	7	15·7	19	17·5
	KJ	−7	−15·7	−27·5	−34·5
	JH	7	15·7	27·5	34·5

In combining the live and dead loads it should be remembered that a live load is more destructive than a dead load of the same nominal amount; especially in the case of a bridge of short span. Hence the net values of the live load, as above found, have been here increased 50 per cent. before adding them to the dead load; the result of the combination being given in the following table:—

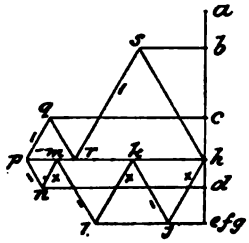


Fig. 70.
Stress Diagram. Case 3.

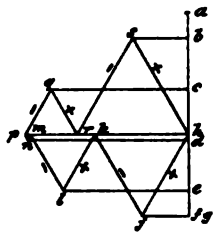


Fig. 71.
Stress Diagram. Case 4.

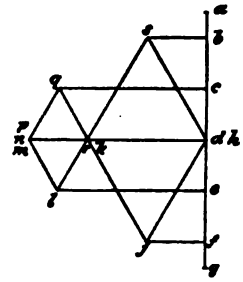


Fig. 72.
Stress Diagram. Case 5.

	Bar.	Stress in tons (Combined).			
		Case 2.	Case 3.	Case 4.	Case 5.
Upper Boom	RH	52	63·5	72·2	74·8
	PH	66·1	92·4	109	113
	MH	55·2	81·9	105	113
	KH	33·5	46·6	64·2	74·8
Lower Boom	BS	-26	-32·6	-35·6	-37·7
	CQ	-59	-86·7	-89·8	-94·3
	DN	-60·8	-87·2	-106	-113
	EL	-44·7	-64·2	-84·5	-94·3
	FJ	-21·8	-22·1	-32·6	-37·7
Diagonals	HS	52	45	71·2	74·8
	SR	-52	-45	-71·2	-74·8
	RQ	14	27·2	34·7	37·8
	QP	-14	-27·2	-34·7	-37·8
	PN	-10·5	-10·5	-2·4	0
	NM	10·5	10·5	2·4	0
	ML	-22·1	-35·2	-40·1	-37·8
	LK	22·1	35·2	40·1	37·8
	KJ	-33·5	-46·6	-64·2	-74·8
	JH	33·5	46·6	64·2	74·8

It will be noticed that the stresses on the diagonals PN and NM vary from nothing to $10\frac{1}{2}$ tons, according to the position of the travelling load. No actual *reversal* of stress here takes place, but such reversal is a possibility when the girder is short and the rolling load large.

In the case of a bridge of fairly long span it is usual to combine the dead and live loads in the first instance, and to neglect the dynamical effect of the live load. This method is illustrated in the following example (Fig. 73):—

A "through" bridge for a double line of railway is constructed with a pair of Linville or N girders of 100 feet span, 10 feet deep, and is divided into ten equal divisions or panels by vertical struts and inclined ties. The weight of the platform and the rolling load is 1·7 ton per foot run on each main girder, this being uniformly distributed along the joints of the lower boom. The weight of each main girder is ·3 ton per foot run, uniformly distributed amongst the upper and lower joints. It is required to draw the stress diagram (Fig. 74).

Here the load on each main girder is 170 tons spread equally over the *lower* boom. The total weight of each girder is 100 times ·3 ton, or 30 tons; half of which must be transferred to the upper boom. Thus the entire load on the *upper* boom is 15 tons, and on the *lower* boom 185 tons; so that the reactions of the abutments will each be 100 tons. After referring these loads to the joints, the load line AL can be drawn for the upper boom, and MV for the lower boom. Taking the joints in proper order, the stress diagram (Fig. 74) can then be completed without difficulty. There is no direct stress in the members VW and MP.

In parallel braced girders it is practically correct to regard the whole of the bending moment as sustained by the flanges or booms, and the whole of the shearing force by the web bracing. Consequently, if we draw a diagram of bending moment, it is easy to deduce from it, quite apart

from a stress diagram, the total stress on any section of the booms; and if we draw a diagram of shearing force, the stresses on the diagonals may also be found without the aid of a stress diagram. In bowstring girders, however, the case is different; much of the shearing force being resisted by the curved bow. In fact, when the curve is a parabola, and the load uniformly distributed, the entire shearing force is balanced by the vertical component of the stress on the arched boom.

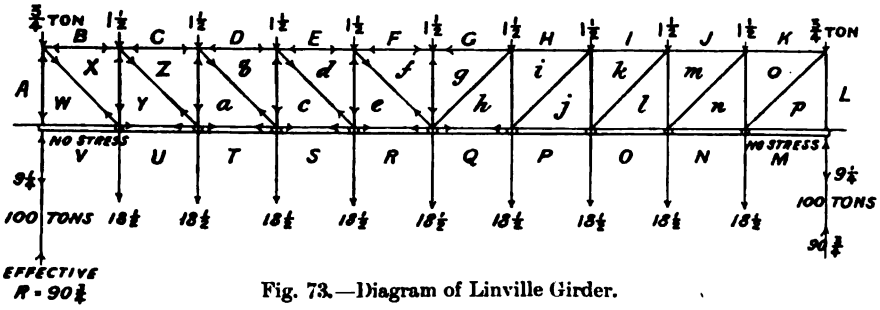


Fig. 73.—Diagram of Linville Girder.

they are much magnified cranes of that type. But they have departed so far from the old Goliaths as to have become a great class by themselves, and as such we must regard them, leaving the **Goliaths** proper to be treated separately.

The bridge crane, Fig. 75, is also a gantry crane, because the bridge is a gantry, and it often carries a crane instead of a trolley or crab. The features which these types have in common are the support of the bridge on end uprights, the portable

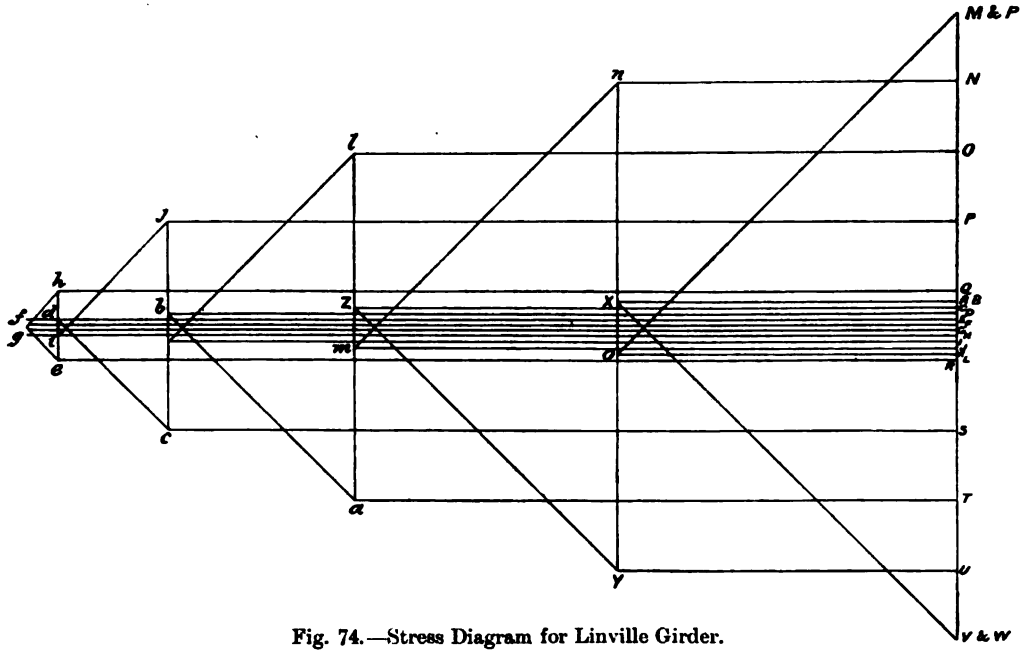


Fig. 74.—Stress Diagram for Linville Girder.

Bridge Crane.—A term which covers a wide range of design of cranes. They should properly be classed with Goliath cranes because character of the structure, and the leaving a clear way beneath the gantry or bridge and between the uprights (the span). All alike are

the descendants of the old timber-framed Wellington cranes in which the trolley traversed the beams of a Goliath type of framing.

The most striking characteristics of the bridge cranes are their enormous span, variety in design, rapidity of action, and wide variations in loads carried. The occasion for their development arose in the iron ore districts of the United States, but their utilities have extended to shipyards, and wharves of all kinds. New problems have arisen in consequence, one of the principal being the diminution of weight, and resistance to air pressure, hence the development of designs of extreme lightness, standards, cantilevers, and beams being alike built with systems of bracing instead of solid plates and of timber. Another thing is that the growth of the bridge

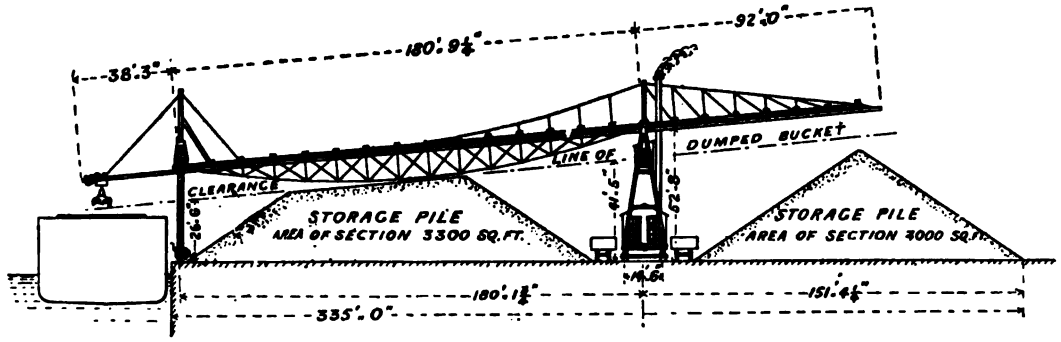


Fig. 75.—Bridge Crane. (The Brown Hoisting Machinery Co.)

cranes has been greatly favoured by the development of the electric drive, which on the individual motor system enables much of the heavy transmission gears of the older Goliath to be dispensed with.

Many of these cranes are of bridge and cantilever type combined, that is the main portion is carried between the travelling piers, while a cantilever hangs out at one or at both ends. In other cases one end is hinged, forming an "apron" so that it can be inclined to suit the depth at which loading or unloading have to be done, and also to be thrown up into a vertical position when not in use, to leave an unobstructed way for the masts of vessels. The spans of some of these cranes range up to 400 feet. Cranes of these types will handle over 600 tons of coal in a day of ten hours, or 2,000 tons or more of iron ore, although as a rule lifting capacity is small. But the material can be hoisted and carried by the trolley a distance of 300 feet, and dumped, and the trolley run back in a minute. From 4 to 5 tons may be taken as an average of loads for which such cranes are designed.

These cranes are built in series for operating over hatches of vessels, and the term *bridge tramway plants* is given to this design, Figs. 76 and 77, Plate VI. The bridge is connected to the front pier or upright by a hinged fitting, which permits the front piers to be adjusted sideways to allow the hinged apron just now mentioned to be accommodated to the hatches of vessels. The operating engines run in one direction, and reversal is effected by a friction clutch. Another bridge crane is shown by Fig. 78, Plate VI.

Bridge Cylinders.—Cylinders sunk in soil on land, or in the beds of streams, on which to erect the piers and abutments of bridges. They are usually made of cast iron united with flanges. Alternatives are steel-plated cylinders, or those of concrete.

Bridge Plates.—The steel plates ordinarily used for bridge work are not of so high a quality as those required for boilers. Specifications vary between a minimum tensile strength of 26 to 28 tons and a maximum of 30 to 32 tons per square inch. Elongation is 20 per cent. on a length of 8 inches. The bending test is that strips 1½ inch wide cut lengthway or crossway, heated uniformly to a low cherry red, and cooled in water of 82° Fahr., must stand bending



Fig. 76.—Plant of Four Bridge Cranes, for North-Western Fuel Co.
(The Brown Hoisting Machinery Co.)



Fig. 77.—Side View of Fig. 76.



Fig. 78.—Plant of Three Bridge Cranes, Electrically Driven, for the North German Coal and Coke Co.
Each Crane Handles over 600 Tons of Coal in Ten Hours. (Adolf Bleichert & Co.) [*To face page* 84.

to a curve of which the inner radius is one and a half times the thickness of steel tested.

Bridge Rail.—A hollow flat bottomed rail, with its flanges to bolt on longitudinal sleepers.

Bridge Stays or **Girder Stays.**—The stays used on top of the fire-boxes of the boilers of locomotives and similar types. They only bear by their ends and at intervals on the crowns, leaving spaces for the circulation of the water.

Bridle.—The loop on one type of slide-valve rod which embraces the back of the slide-valve. Also a clip used in a testing machine for holding specimen pieces.

Bright Work.—Machined work as distinguished from Black Work. *See* **Black Fit.**

Brine Pump.—A plunger .pump used in the ammonia refrigerating system, for pumping the brine through the coils of cooling pipes. The working parts are made of bronze. The pump is either a vertical barrel pump, or a horizontal duplex type.

Briquette Machinery.—This comprises a heater fed with steam, in which the materials fine coal, and pitch, &c., are mixed and thoroughly amalgamated, thence being passed into a measuring chamber, leading to a feeding box, which charges the moulds. The latter subsequently come under compressing rams, which squeeze the briquettes at a pressure of about two tons to the square inch. They are subsequently ejected, and passed down a shute on to a band or other conveyor, in the most complete plants. A preliminary adjunct to the compressing machinery is a pulveriser, for grinding up the coal, &c., into a sufficiently fine state.

Britannia Metal.—Introduced in 1770. Its composition is $3\frac{1}{2}$ cwt. of block tin, 28 lb. antimony, 8 lb. copper, 8 lb. brass, cast into ingots and rolled.

British Thermal Unit, or **B.Th.U.**—This is the amount of heat necessary to raise the temperature of 1 lb. of water at or near 32° Fahr. through 1° Fahr. Dr Joule found that by the expenditure of one unit of heat a weight of 772 lb. could be raised one foot high. Hence the B.Th.U. = 772 ft. lb. Heat therefore requires for its production 772 ft. lb. of mechanical work for each unit. Or conversely it yields by its disappearance 772 ft. lb. of work. In the metric system the unit of heat is the calorie, or the amount of heat necessary to raise the temperature of 1 kilogramme of water through 1° Cent. For conversion 1 cal. = 3·968 B.Th.U. and 1 B.Th.U. = 0·252 cal. The relation is obtained thus:—1 kilo = 2·204 lb. and 1° C. = $\frac{9}{5}$° Fahr. The ratio therefore is $2{\cdot}204 \times 9 \div 5 = 3{\cdot}968$, the reciprocal of which is 0·252. A sufficiently exact approximation is the ratio of 4 : 1.

Broach.—This term may be applied to any type of reamer, since the forms and functions of both are identical. The word usually means the rose reamer, or else the hexagonal section; the latter is usually tapered. *See* **Reamers.**

Broaching also **Reamering** or **Reaming.**—The operation of finishing holes for the reception of pins or bolts, after the drilling has been done. Broaching is necessary while a machine is being erected, after parts have been set in correct position, and the bolt holes do not happen to coincide. The broach is then run through, making a true hole generally to receive a turned bolt. Holes are often drilled purposely under size to allow sufficient metal for the subsequent broaching.

The word is used in America to denote **Drifting**, and the machine when such is used is called a broaching press.

Broad Cutting.—The finishing cuts taken in planer, lathe, and other machines, using single edged tools. The term is relative only, since a broad cut may range anywhere between say $\frac{1}{4}$ in. and 2 in. It is always very shallow, and the amount of traverse feed is apparent on the finished surface.

Broken Castings — Moulding from.—The applications of this work are extensive in general and jobbing engineering. Some moulders are very adept at turning out decent castings from a break-down job when there would be no time to make a pattern, for which also the expense might be prohibitive. The following summarises the leading points to be regarded in doing such work, which is necessarily of a makeshift character. In this also is included the utilisation of badly worn castings.

When several castings are required all alike, there is never any question about using broken or worn castings. When the employment of such

castings involves as much as or more preliminary preparation than that of making a new pattern of wood they are not employed. There must be economy to justify their use.

After this the following points arise. The nature of the surfaces as affecting delivery, the facilities or otherwise which exist for delivery, such as the need of cores, or drawbacks, or numerous mould joints. The degree of fracture, and number, and location of broken parts which would sometimes prevent proper piecing together in the mould. Shrinkage in some cases would result in the castings coming out too small for their functions, and in addition allowances for tooling may have to be added. A casting badly worn must be thickened up before it can be moulded from.

Before a casting can be moulded from, it must be cleaned, generally done by placing it in a clear fire to burn off all grease, scale, and dirt. It is then allowed to cool, and brushed with card wire, and the pattern-maker takes it in hand.

If the surfaces are too rough to deliver properly, they are smoothed with a coarse file, or ground, or if badly corroded, they may be covered with a filling of beeswax, or chalk mixed with shellac varnish, which, when hardened, can be rubbed down with glasspaper, and varnished. Smoothly-turned surfaces may be beeswaxed.

When the fractured parts can be laid accurately together in the mould, no means of fastening is adopted, but if otherwise they are united in various ways, by screws, rivets, plates, &c.; or if there is a hole available, as in a broken boss, by driving a wooden plug through the hole, to which the boss pieces can be fastened by various means, such as those employed for attaching extra thickness pieces on faces and diameters, to compensate for shrinkage, and for tooling allowances. Holes are drilled in the metal, and plugged with wood to receive nails or screws, or faces are cemented, or the extras are simply laid in position at the time of ramming. Sometimes a good extra rapping suffices to give shrinkage, or tooling allowance, but this is only available in small work, and for slight allowances. The allowances for boring in holes are readily made by plugging the holes, and making a print on the end of the plug with the proper allowance for boring.

To get castings out of the mould is often difficult, due partly to their roughness, partly to the lack of lifting holes, chiefly to the undercutting, or recessing by coring, or otherwise, which is present.

Roughness of surface may be got over by the methods already given, the want of lifting holes is met either by drilling and tapping such holes in the casting, or by inserting the hands under the casting, and making the sand good subsequently, or by laying wire underneath, and round the casting, and lifting by that. The undercutting or coring is met by employing cores, or drawbacks, for which provision has to be made beforehand. Castings that would originally be made from jointed patterns must therefore, if moulded from, be cored out. Moreover the jointing of regular patterns is often more favourable to clean delivery than that of broken castings. A few examples will illustrate the foregoing observations.

Broken gear wheels are frequently brought in, having an arm snapped, or a piece of the rim broken out, or two or three teeth fractured. It is often cheaper to prepare the parts for a machine-moulded wheel, and make a new one in that way, than to get up the casting for moulding. But if prepared, it can only be done economically when the arms are of T section, or elliptical section. If of H section the arms must be cored out. The teeth must generally be smoothed with a file. Allowances for shrinkage cannot be made on wheels, so that if centres are fixed the method of utilising broken castings cannot be adopted. Broken teeth can be patched up with wood; drilling, and plugging holes to receive nails for attachment of the teeth portions. As the teeth are generally worn on the flanks, make-up pattern teeth must be supplied to the moulder for making good the mould in detail.

There is a large class of work, of which sheave pulleys are representative, liable to fracture, and which if moulded from, must have the interior of the rim cored out. A ring print is then worked round the edge of the casting to form the circular print impression to receive the cores in segmental lengths. The segment prints may fit within the rim, or by the edges only, and be maintained level with batten strips.

Other jobs that require coring are double

brackets, the jib heads of derrick cranes, and work of that class, in which two cheeks or plates enclose a space which cannot deliver from an unjointed casting. The space is filled up, and prints coming out at the sides leave the impressions for cores. In all such cases core boxes have to be made, and sometimes no more time would be occupied in making a jointed pattern to deliver itself, than to clean up and print a casting and make a core box, with the added time required for moulding.

If we take an extreme case it is obvious that there could be no economy in making a mould from an engine cylinder, because the core box work involved would be in excess of the time saved in the mere pattern work.

The most suitable cases that arise for moulding from broken castings are those of plain sole and bed plates, plain cheeks, standards, mortar pan bottoms, and similar articles of no great depth, and having no undercutting.

Lead is also laid round turned or bored portions to give allowances for shrinkage and tooling. *See* **Alterations to Patterns**, Figs. 44, 45.

One of the difficulties incidental to moulding from badly broken parts is that of laying and maintaining them truly in place. A level sand bed is often the best foundation for this. If the work is not absolutely level, the bed may still be necessary, in which recesses can be dug to receive lugs, bosses, &c. Parts must often be checked with rules, squares, straightedges, and calipers, at the time of ramming, and the moulding must often be followed by an excessive amount of mending up.

Broken Moulds.—These are regarded in many shops as almost unavoidable evils, to which, with rare exceptions, all moulds are liable. The present article will point out the causes of, and remedies for fractured moulds, and the best methods of repair when such occur.

Moulds break down on the delivery of the pattern, or subsequently. The cause may lie with the pattern, the moulder, or his tackle.

The pattern is responsible when it has no taper, or taper insufficient in amount relatively to its depth, or method of lift,—requiring more as depth increases, and more in the top than in the bottom. Risk may often be lessened by making pieces loose instead of fast. A pattern jointed badly, giving too deep a perpendicular lift will cause fracture. Timber joints overlapping will have the same result, as also will rough surfaces;—due to plane marks, roughened grain, warped faces, screw heads, or nail heads projecting, and holes left unstopped, these being among the principal causes.

The moulder is responsible when he does not rap sufficiently, when he does not lift perpendicularly, but allows the pattern to bear harder against one side than the other, when he fails to press the surface of the sand down on the first sign of a fracture, before withdrawing further. He risks broken moulds by neglecting to swab the edges just before withdrawal, or by not nailing weak sections of sand, or not liftering sufficiently. After the mould is made, fracture may occur by crushing, due to insufficient finning, or to pressure on cores, or by rough handling in turning over.

The tackle is responsible for broken moulds when box pins fit badly, and when they are too short to serve as guides in lifting a top. Flimsy boxes are responsible for many fractures through the sand. Jerky movements of tackle cause fractures in turning over and closing.

The vast majority of broken moulds are incidental to hand moulding. They diminish in plate moulding, and should seldom occur in moulding done on machines, one of the chief advantages of which is the perpendicular lift.

The methods of mending up broken moulds are as follows:—

Brass-founders and iron-founders when dealing with small patterns frequently put the pattern back bodily into the mould, press it down, make the broken edges good, and withdraw again. This is only available in moulds not exceeding a medium depth, or those having curved sections. The greater amount of mending up is done with pieces either removed from the pattern for the purpose, or made separately, or picked up at random and utilised.

If wheel teeth break down, two or three loose teeth are inserted, and the sand rammed round them. If a straight edge of sand is broken, any straight strip of wood will serve to hold against its face as a guide for making

good by, and this device is extended into curved outlines. A strip may be simply held against a broken face, or it may fill up a rib space entirely, so leaving the hands of the moulder free for work.

Nailing is often necessary in badly broken edges. The nails, or rods, or both are inserted, previously moistened with clay wash, and the sand made good around, and sleeked with the trowel, after which the making-up piece is removed. As clay wash and the swab are used in this work, the section so made good is often skin-dried with a heater, or oil is poured over it, to allow the metal to lay quietly.

Bronze.—When tin is added to copper, bronze, or gun-metal results. The proportions most commonly used lie between 85 and 91 per cent. of copper and 15 to 9 per cent. of tin; 10 or 11 per cent. of tin is a usual proportion, at which the alloy is of a yellow colour. Strength diminishes with large additions of tin, so that beyond 20 per cent. the increased compressive strength is obtained at a sacrifice of ductility. Below 17·5 per cent. the elastic limit lies between 50 and 60 per cent. of the ultimate strength; beyond this the proportion rises, and with 25 per cent. of tin the elastic limit and breaking point coincide.

But the term bronze is used in a very loose manner, since much that is so called is strictly speaking, brass. Copper and tin make bronze, copper and zinc brass. And yet the so-called *Compound Bronzes* which contain copper, tin, zinc, and lead, and other elements are extremely valuable, without even including the aluminium, phosphor, manganese, silicon, and steel bronzes.

The bronzes and brasses have a lower melting point than copper, and a higher than tin. They become harder than either of their principal constituents, with increase of tin, and they are less liable to oxidation. Zinc is valuable as a deoxidant, but while reducing the oxides it lowers the elastic limit, and softens the alloy. Phosphorus is a deoxidant, and it hardens an alloy.

Professor Thurston found that the best alloys for purposes demanding toughness and strength lie between 58 and 54 per cent. of copper, 44 and 40 per cent. of zinc, and $2\frac{1}{2}$ and $\frac{1}{2}$ per cent. of tin. The strongest contained 57 per cent. copper, 42 per cent. zinc, and 1 per cent. tin. A more generally useful alloy is 56 per cent. copper, 42 per cent. zinc, 2 per cent. tin. The most ductile brass contains 57 per cent. copper, and 43 per cent. tin. The composition of the common brasses ranges from 67 to 70 parts of copper, to 33 to 30 of zinc, or two-thirds to one-third, $66\frac{2}{3}$ copper to $33\frac{1}{3}$ tin. When lead is added, that is for the purpose of cheapening and softening; tin is added to strengthen it. Brass occurs in a very wide range of qualities from a tough mixture approaching that of gun-metal, to the ductile stuff used in cheap goods.

TYPICAL BRONZES AND BRASSES.

	Copper.	Tin.	Zinc.	Lead.
Common Bronze -	89	11	...	...
For Slide Valves -	82·5	14·5	...	...
For Bearings - -	79	21	...	...
Compound Bronzes-	87·5	12·5	2	0·5
,, ,, -	80 to 88	18 to 10	2	0·5
,, ,, -	85	11·6	3·9	...
,, ,, -	83·5	6·0	...	10
,, ,, -	20	1	0·25	2·5
,, ,, -	86	8	4	2
,, ,, -	64	4	3·5	1·5
,, ,, -	32	3	3	1
,, ,, -	64	9·5	3·5	1·5
,, ,, -	87	8	5	...
Brass - - -	1	...	0·5	...
,, - - -	86	7	4	2
,, - - -	86	12	0·5	0·5
Brass for Tubes -	70	...	30	...
,, ,, -	70	1	29	...
,, ,, -	68	...	32	...
Yellow Brass -	16	...	8	0·25
,, ,, -	16	...	5	0·5
,, ,, -	16	...	3	...
,, ,, -	16	0·4	11	...
Red Brass - -	20	2	3	...
,, ,, - -	20	4	3	...
,, ,, - -	20	3	4	...

Bronze Powder.—A preparation used to impart the appearance of bronze to iron or other metal. The powder from Dutch metal is used, rubbed with gum and laid on with a chamois leather on a varnish of gold size. Tin sulphide is also used, one part of sulphide to six parts of bone ash, and rubbed on with a linen pad, moistened. Various alloys of copper with tin or with zinc are also used. It is essential that the powder be reduced to an extremely fine condition.

Bronzing.—The mechanical operation of

colouring metal work. It is accomplished by rubbing or brushing the bronze powders over the work, rendered tacky with gold size, on a surface previously japanned and dried.

Bronzing is also of a chemical character, in that case termed *wet colouring*. In this, copper is one of the principal agents. The object in these cases is to expose the metals to solutions which produce chemical changes on the surface, and so yield coloured compounds of the metal with other elements, as oxygen, sulphur, &c. Different metals require solutions differing therefore in composition; iron, copper, brass, tin, &c.; so that the subject is very diverse and extensive in character, and too highly specialised for a concise method of treatment.

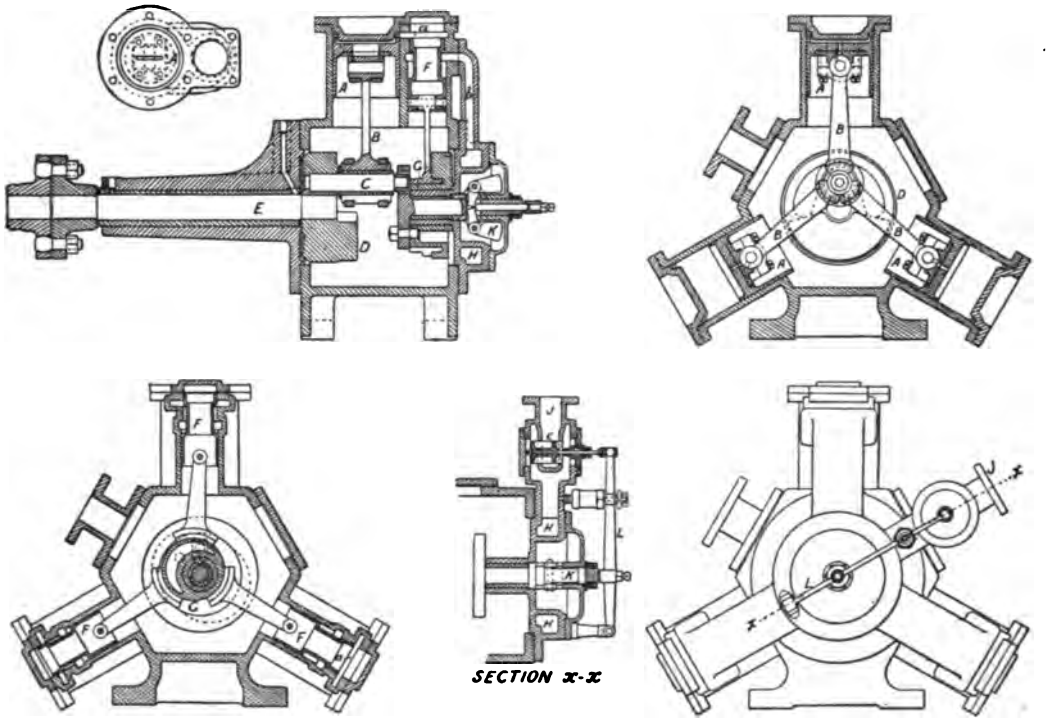


Fig. 79.—"Brotherhood" Three-Cylinder Engine.

Brotherhood Three-Cylinder Engines.—These are the most successful type of engines of this class yet produced, having been employed for many years for electric light installations, and for driving portable and other machines, large and small, and as the propelling agency for torpedoes. They are suitable alike for driving by steam, compressed air, and water, and are generally single acting. One design is made reversible.

The features of these engines are apparent from Fig. 79. The cylinders are in one casting with a foot, the steam passages are in a separate casting bolted thereto. The three trunk-pistons A have their rods B loosely pivoted so that they shall be free to impart an eccentric movement to their common pin C, the path of which is controlled by the crank disc D on the shaft E which transmits the motion of the engines. The piston valves F, also with pivoted rods, are actuated by an eccentric G, so opening the ports *a* in turn. The steam supply comes through the passages *b* in a separate casing, from the common steam-chest H, J being the steam inlet. The supply is regulated by the governor K which actuates the lever L and the throttle *c*.

The engine being single acting, the pistons and rods are always in compression, which avoids alternating stresses; while the three-cylinder arrangement avoids dead points, and the engine can therefore be started in any

position. The reversing engine is shown in Fig. 80. Steam is admitted to turn the piston rods to one side or other of the centre by the movement of the lever seen. This rotates a block through an arc of a circle, bringing one or another steam opening opposite to the passage.

Brown & Sharpe, or **American Wire Gauge.**—This is a standard gauge largely employed in America; the sizes are given below, in decimal parts of the inch:—

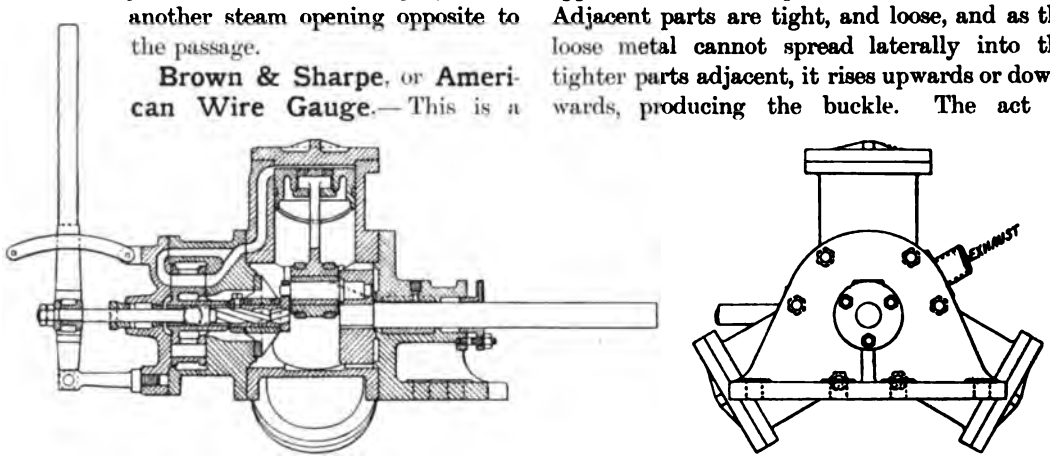


Fig. 80.—"Brotherhood" Three-Cylinder Engine.

Number.	Size.	Number.	Size.
000000	...	18	·040303
00000	...	19	·03589
0000	·46	20	·031961
000	·40964	21	·028462
00	·3648	22	·025347
0	·32486	23	·022571
1	·2893	24	·0201
2	·25763	25	·0179
3	·22942	26	01594
4	·20431	27	·014195
5	·18194	28	·012641
6	·16202	29	·011257
7	·14428	30	·010025
8	·12849	31	·008928
9	·11443	32	·00795
10	·10189	33	·00708
11	·090742	34	·006304
12	·080808	35	005614
13	·071961	36	·005
14	·064084	37	·004453
15	·057068	38	·003965
16	·05082	39	·003531
17	·045257	40	·003144

Brown Prints.—*See* **Photo Prints.**

Bucket Pump.—*See* **Suction Pump.**

Buckle.—Signifies a condition of unequal tension in sheets and plates, which becomes apparent in their departure from a true plane. Adjacent parts are tight, and loose, and as the loose metal cannot spread laterally into the tighter parts adjacent, it rises upwards or downwards, producing the buckle. The act of removing buckle consists, not in hammering the buckled part, but the encircling metal, which holds it fast. The surrounding metal being hammered, stretches, leaving the buckle free to extend sideways. The art can only be acquired by much practice, and it is easy to render the last state of a plate worse than the first by injudicious treatment.

Buckle Plate.—A plate of cast iron, or steel-plated, used to support a roadway or footpath over a bridge. It derives its name from the fact that its surface is not plane, but cambered, or bent upwards to the extent of 3 in. or 4 in., on the principle of the arch, only that its surface is usually faceted instead of being curved.

Buckstaves.—The metal plates that are bolted up the sides of brick-work furnaces.

Buddle.—A concentrating machine for ores. It is either a hand buddle, or power driven. The first is a rectangular box with a sloping bottom into which a stream of ore and waste is fed gradually, forming a deposit of varying richness. Power-driven buddles have convex, or concave bottoms. In the first the stream is fed in at the centre, in the second at the circumference, so that the richest deposits are nearer the centre and circumference respectively when they are dug out.

Buffer.—Locomotives, and railway carriages and wagons, are provided with buffers fitted with springs which, on being compressed, cushion and neutralise the shock produced by striking other railway vehicles (as in shunting operations, coupling up, &c.), or when coming in slight contact with buffer-stops, or when the brake is suddenly applied to a train while running at a good speed.

by a nut, or by a steel ring, as in Fig. 81. The casing is hollow and contains a spring, which may consist of indiarubber rings separated by wrought-iron washers, Fig. 81, or it may be made of coiled steel, either volute or spiral in form. When the plunger is pushed inwards the spring is compressed, and the effect of one vehicle striking another is thus minimised. Buffers of this description are used for engines

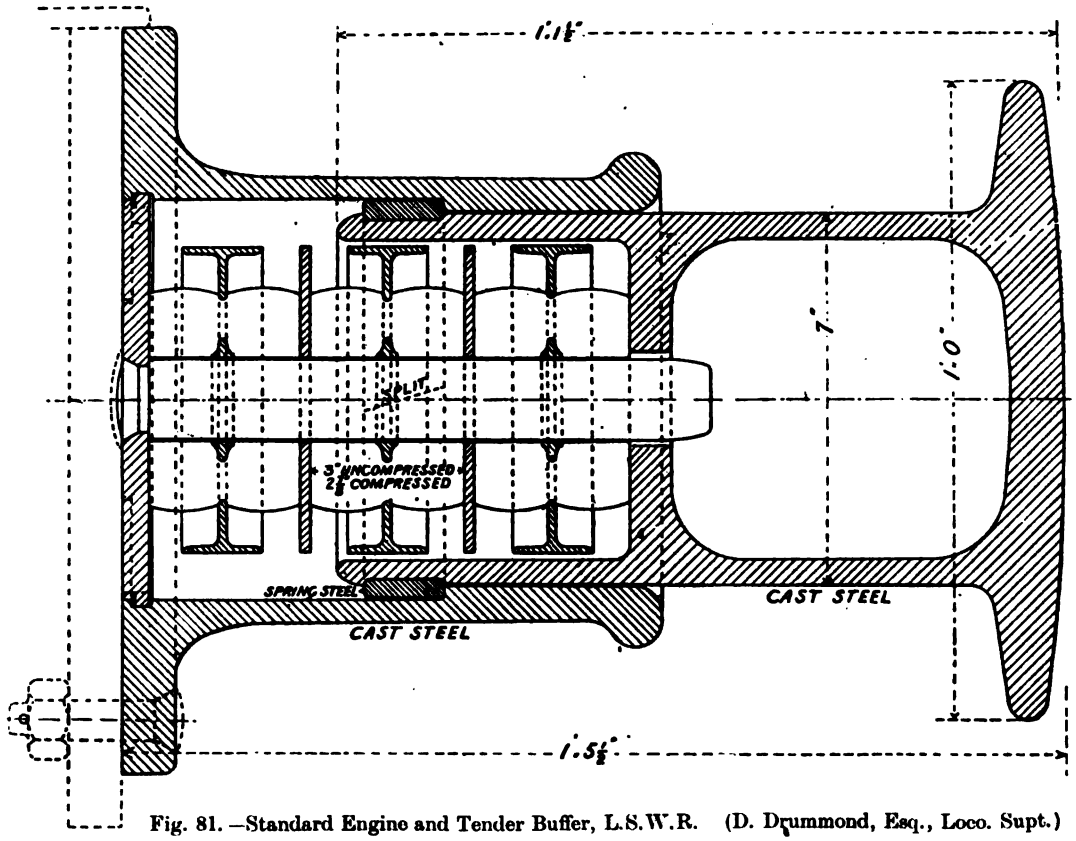


Fig. 81.—Standard Engine and Tender Buffer, L.S.W.R. (D. Drummond, Esq., Loco. Supt.)

The buffers consist of two principal parts, the plunger and the casing, respectively. The latter is bolted to the buffer beam, which is generally of steel plate, except in the case of wooden wagons. The plunger works partly inside the casing, and its striking end is usually circular in shape, but in the case of carriages and the larger types of wagons, it is sometimes made elliptical. It is held in position by a long bolt, which passes through it and the casing, and the bolt is secured at the back of the latter

and carriages, and also for certain types of wagons. Each engine or vehicle has a pair of buffers at each end, placed with their centres about 3 ft. 6 in. above the level of the rails, and from 5 ft. 6 in. to 5 ft. 9 in. apart transversely.

Railway wagons of the ordinary kind at one time had "dead," or solid buffers, made of wood, but they are now mostly fitted with buffers controlled by springs, Fig. 82. The casings are without springs, and in place of these there are two large laminated or plate

springs (one at each end), fitted at a suitable distance behind the buffer beams, and the two ends of each spring are connected to the corresponding plunger bolts, which are extended back for the purpose.

An equalising arrangement of buffers for railway carriages was devised some years ago by Mr F. W. Webb, the former Chief Mechanical Engineer of the London and North-Western Railway. The object of this arrangement was to remedy the defect which exists with ordinary buffers, in that the strains which are set up when a train is running round a curve are thrown on the buffers on one side only. In order to equally divide the strains thus imposed, Mr Webb's arrangement provides for each buffer beam two bell-cranks, which are opposite each other, and are pivoted to the frame on each side of the vehicle. These cranks are coupled together transversely by rods which are always in tension, the other arm of each crank being used for the abutment of a spiral spring, against which the buffer stem presses. Consequently, when the buffers on one side of the vehicles of a train are pressed home, those on the opposite side, owing to the action of the bell-cranks, are extended by the same amount, so that all the buffers are kept continually in contact, thereby ensuring greater steadiness in running generally, and less friction when passing round curves. The springs referred to are placed immediately behind the buffer beams, and opposite their respective buffers, and the plunger stems are carried through them. Thus each buffer is provided with a spring, which is arranged as stated, instead of being fitted inside the casing.

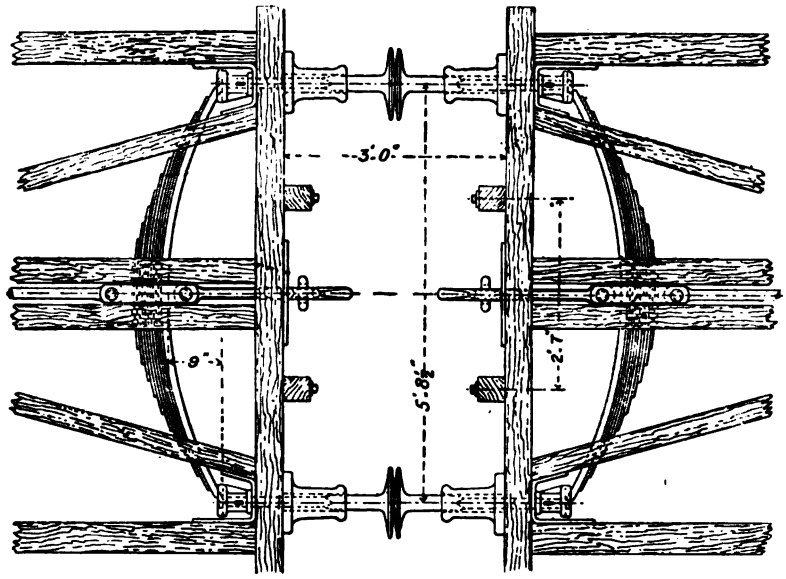


Fig. 82.—Standard Draw and Buffing Gear, for wagons, L.S.W.R. (W. Panter, Esq., Carriage and Wagon Supt.)

Buff-Wheel.—*See* **Polishing-Wheels.**

Builders' Castings.—The importance of these is so great that many firms lay themselves out largely or exclusively for these classes of work, or for sections of the same. Castings have a large range of utility in constructional work, and realise the architectural canons of stability, utility, and beauty. Cast work has been displaced from some of its older applications, notably in girder work, for which the lighter, more elastic and ductile steel is to be preferred. But when rigidity and strength to oppose purely compressive stresses are required, and when ornament is wanted, cast iron fills a most valuable place. The following are its principal applications in these spheres, most of which will receive suitable detailed treatment under their own headings in these volumes.

Columns are cast in plain and highly ornate types, and when proper care is observed in designing and casting they are as safe as steel-plated columns can be. The stanchion, also often cast, is in principle a column. Allied to columns are foundation cylinders, and screw piles, both very generally cast. Any lengths can be made up by bolting together sections through flanges. In bridge work, though plating and bracing are usually adopted, cast iron is often employed for buckle plates to support pathways, and for

ornamental parapets and railings, and ornamental mouldings covering otherwise gaunt areas. The piers and abutments of bridges are often made of cast iron, and also the expansion plates and rollers. Tanks are built up of cast-iron plates, with flanges and bolts. Numerous cantilevers, brackets, and corbels are cast, and highly ornamented. Timber roofs have their shoes of cast iron, cored out. For all kinds of gratings, plain and ornamental, cast iron stands alone. Sink traps, inspection chambers, hydrant work, manholes, penstocks, sewer flaps, fire-cock frames, and other sanitary and municipal appliances are cast; iron pipes and bends, pipes for hot water and rain water are cast, as also are those for gas and water supply in all their forms, with spigots, sockets, flanges, bends, tees, reducing pieces, &c.

The builder therefore has a keen interest in cast work, since his practice involves its extensive employment. He should acquire a workable knowledge of the differences between good and bad work, and understand a good deal of the art of making patterns and moulds. Plain patterns might often be made in a carpenter's shop under proper supervision, and the differences between suitable and improper methods of moulding, and the differences in qualities of metal should be known by a builder, much of whose work lies in cast iron.

Builders' Machinery. — This comprises bullock and horse gears, concrete mixers, cranes, grinding mills, hoisting engines, mortar mixers, portable engines, pumps, winches; descriptions of each will be found under their headings.

Building-up.—*See* **Boxing-up, Lagging, Segmental Work.**

Bulb Bars.—Denotes three kinds of rolled sections, having one edge thickened with a bulb for increase of strength, and used in shipbuilding. Fig. 83 shows the three forms, and proportions specified by "Lloyds" for bulb plates or bars, bulb tees, and bulb angles. The depth D in inches of the section is the unit from which the other dimensions are deduced. The widths of the bulbs are $3\frac{1}{4}$ C for plates and tees, and $2\frac{1}{2}$ C for angles; where $C = \frac{D+1}{20}$ for plates and tees, and $\frac{D+3}{20}$ for angles, with the other proportions as given in the sketches.

The standard thickness for regulating the width of bulb of beams and bars, the depth of which is not an exact number of inches, should correspond to the depth in inches next below the actual depth, thus: for tee beams and bulb plates, $10\frac{1}{2}$ inches deep, the standard thickness for determining the dimensions of the bulb should be $\frac{10+1}{20}$ or $\frac{11}{20}$.

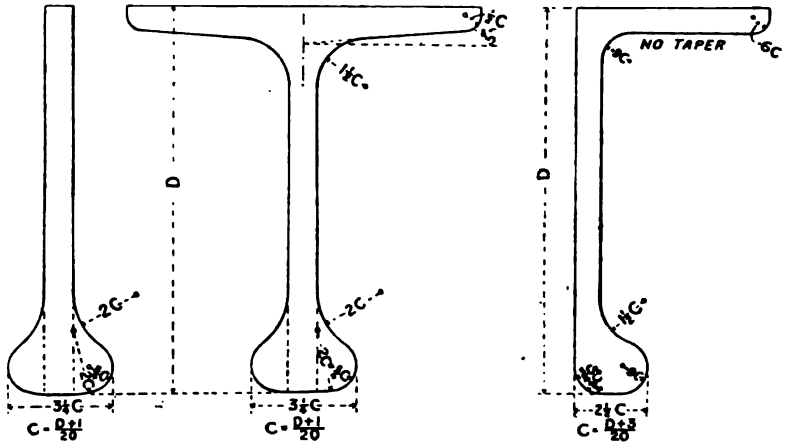


Fig. 83.—Bulb Bars.

Bulk—Articles in.—It is desirable to know the space or volume occupied by numerous articles in bulk, and it is generally reckoned as the weight of a cubic foot, and as so many cubic feet per ton.

Bulkhead.—There are numerous regulations for the bulkheads of steam vessels. Some of the most important are as follows:—At each end of the engine and boiler space there must be a watertight bulkhead to extend from the floor plates to the upper deck, or to the spar deck, or the main deck, according to the class of vessel. The after bulkhead through which the screw

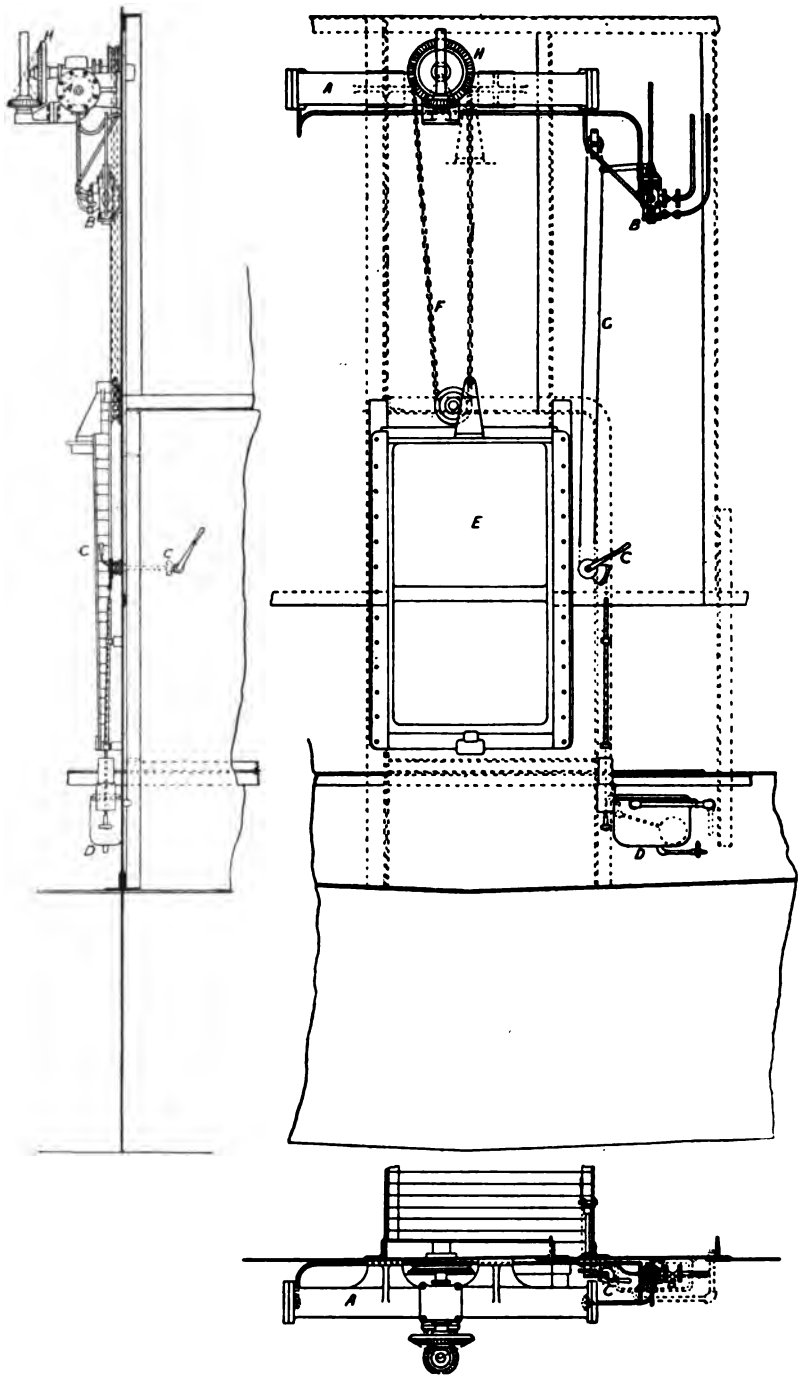


Fig. 84.—Stone-Lloyd Bulkhead Door.

REFERENCES:—*A*. Hydraulic cylinder. *B*. Controlling valve. *C*. Controlling handles. *D*. Bilge float apparatus. *E*. Sliding door. *F*. Chain drive. *G*. Guide pulley wire rope. *H*. Bevel gears for operating door chains, by hand.

shaft passes has to be watertight in the stuffing box. Bulkheads are to be fitted first at not less than one-twentieth of the vessel's length abaft the stem at the lower deck, and another at a reasonable distance from the after end. With increase in the length of vessels, intermediate bulkheads are fitted in greater numbers, until, in vessels between 540 feet and 600 feet in length, nine bulkheads have to be fitted, and the heights vary also with the class of vessel. A regular scale of plate thicknesses is given, ranging from $\frac{5}{20}$ in. to $\frac{9}{20}$ in., and of angles from $2\frac{1}{2}$ in. × $2\frac{1}{2}$ in. × $\frac{5}{20}$ in. to 7 in. × $3\frac{1}{2}$ in. × $\frac{11}{20}$ in. Provision is also made for vertical stiffening webs to bulkheads of large sizes. Joints are caulked; some are tested by filling with water, others by water from a hose.

Bulkhead Doors.—The division of ships' hulls into compartments is necessary primarily to give structural strength, but the advantage of providing doors which when closed would make each separate compartment watertight was naturally perceived in the early days of iron shipbuilding. But it was not until the twentieth century had well commenced that an entirely satisfactory method of working the doors was evolved, in what is known as the Stone-Lloyd system. If the system falls short of perfection it is because the necessity of closing doors in time of danger is in itself open to objections. In this, which is being installed in many of the best modern vessels, the defects of previous methods have been eliminated.

The bulkhead doors of a ship fitted with this system may be operated as follows. They may be closed singly, or collectively by a controller on the bridge, where there is also an automatic indicator which shows what doors are opened or closed. They may be operated by controllers on deck above each door, or by controllers on each side of each door. This latter is an important improvement because it always permits the door to be opened by anyone who wishes to pass through, while the possibility of the door being left open is safeguarded against by causing it to close automatically. The doors may also be closed automatically by an inflow of water, which raises a float, and closes the doors of the compartments the water is rising in. All this is done by bringing into operation the hydraulic power which operates the doors; but in addition to this, hand gear is fitted, by which the doors may be worked either from the deck or in the compartments, in case the hydraulic power cannot be used. Further, the doors may close automatically through any failure of the mechanism which operates them; or a door may be dropped suddenly by releasing a clutch. The doors usually slide vertically, though horizontal and cleaving action types are also in use.

When water is rushing into a compartment it is important that doors should be closed as rapidly as possible, but the rapid closing is objectionable and dangerous in itself, so it has now been found advisable to slightly sacrifice speed, and to compensate for it by having the entire system of doors under such perfect control that they may all be closed in a few seconds if necessary. When closed from the bridge, the officer cannot move the controlling lever until he has unscrewed a handwheel. This occupies about twenty seconds, and starts an electric gong ringing in each compartment. Then the doors close at a moderate rate, and can be arrested and reopened if necessary by the controllers on each side of them. These consist of a hand lever which operates a needle valve that temporarily reverses the pressure, opens the door, and then allows it to close again automatically when the lever is released. Although the doors descend rather slowly it is necessary at the same time that they should be forced down with sufficient power to cut through ordinary obstacles, such as lumps of coal, which by keeping the door from closing would render it useless.

Hydraulic power is considered the most suitable means for operation. In the early Stone-Lloyd installations doors were raised and lowered by the direct action of a piston working in a vertical cylinder. An improvement on this was to draw the doors up and down by chains working on sprocket wheels, the cylinder which actuates the wheels being bolted to the door frame, as in Fig. 84. As these sheets have been going through the press, another method has been substituted, that of spur-wheel and rack-gearing. The advantage of this is that all the gear is self-contained, and is not affected by the movements of the

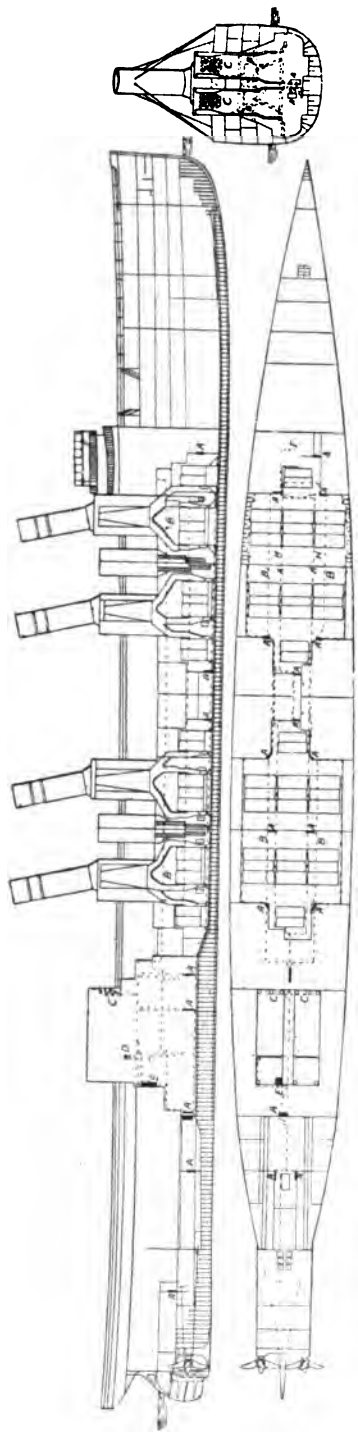


Fig. 85.—The *Deutschland*, fitted with Stone-Lloyd Doors.

A. Doors. *B.* Pressure main. *C.* Accumulators. *D.* High-pressure pump. *E.* 500 gallon tank. *F.* Distribution box. *G.* Pilot mains. *H.* Exhaust main. *I.* 200 gallon tank.

bulkheads, being moreover cheaply and rapidly erected.

The power to operate the doors is obtained from a hydraulic pump in the engine-room, driven by steam from the boiler, and storing the pressure in accumulators. *See* Fig. 85. These accumulators supply sufficient force to close all the doors when the pump is not working. They are employed to maintain an unvarying pressure throughout the system, and also to avoid depending entirely on the pump. They are constructed with an air space between the steam and water cylinders, and the rams are separate, being connected only by steel tie rods, so that the pressure fluid shall not get heated. As the mains containing the pressure fluid have in many cases to pass close to boilers and steam pipes, a constant circulation is also necessary to maintain a low and even temperature. To prevent freezing, the pressure fluid consists of three parts of water to one part of glycerine. The glycerine also preserves leathers and packings, and lubricates working parts.

In communication with the accumulators is a pressure main running the entire length of the ship. Each door has its own hydraulic cylinder, with a valve connecting either end of the cylinder with the pressure and exhaust pipes. The exhaust main, which also runs the entire length of the ship, exhausts into a tank in the engine-room. From here the pressure fluid is pumped back into the supply tank above the water line, and is pumped again into the accumulators. A branch from the pressure main rises to the bridge, and from thence the pressure can be turned into either of two smaller pilot mains running the length of the ship, one for opening doors and the other for closing them. The control of each door at its bulkhead is subsidiary to the bridge control unless communication with the bridge is cut off, as it may be if required, by means of a special valve. But under ordinary conditions, if the door is closed or open from the bridge, it can only be reversed temporarily by the local control, and then automatically reverts to its former position. The same thing also applies if the pressure is on from the automatic bilge float. This connection can also be cut off if required, or local hydraulic control can be cut

off, so that the door can only be worked by the hand gear.

The control valve to each of the hydraulic cylinders is a plain slide or D-valve. It is held to its seat by the supply pressure, and it connects the supply or the exhaust pipe to either end of the cylinder. The valve is moved by a small piston arranged so that water may be admitted to either side. One side of this piston is of greater effective area than the other, and when water is admitted to this side it has the effect of closing the door. If water is admitted to both sides of the valve piston the consequence still is that the door closes. If pressure is not on from either of the other sources, the door will remain open or shut, or in any intermediate position, according to the position of the controlling levers on either side of the bulkhead.

In order to make the doors watertight something more than a mere sliding fit is necessary. The method formerly was to obtain the requisite pressure against the seating by wedges with an inclination of about 1 in 8. These were fitted in the grooves the door slid in, and as the door closed they automatically forced it tightly against its seating. An improvement on that method is the cam action door, in which the door closes first, and then, by a continuation of the movement of the rod which closes it, a number of cams are operated, which press the door tightly against the seating it slides against. These cams press at intervals all round the seating and exert more pressure with less expenditure of energy than is required for the wedge action door. In opening, the action is reversed, the rod first unlocking the door by turning the cams, and then moving the door itself. The cam mechanism is encased to protect it from injury.

The horizontal sliding door has been preferred by the Admiralty for use in the Navy, and is also adopted in foreign navies. The same system of working is of course applicable to it, and also to the cleaving action door, which is designed to more effectively cut its way through obstacles than a direct moving door can. This door has not been used so much as the other types, but it is specially adapted for watertight coal bunkers, where the doorways are often blocked with coal.

This system is applicable to all classes of vessels with bulkhead doors. It has been adopted by the Norddeutscher-Lloyd, the Hamburg American Line, and the Compagnie Générale Transatlantique, for all the passenger steamers belonging to these companies. British firms have been slower in adopting it, but the Cunard Co. have had the *Caronia* and *Carmania* fitted with it, and the two express leviathan liners built on the Clyde and Tyne are thus provided. Also numerous small passenger steamers belonging to the S.E. & C.R., and the L. & N.W. railway companies.

In view of the increasing size and value of vessels, and the passengers' demand for safety, there can be no doubt that a system of this sort is certain to replace the old methods of operating bulkhead doors. In several notable cases vessels have been lost which certainly would not have been if the doors could have been closed in time. Where the doors had to be closed individually by hand it was sometimes not possible to do it, and where they were closed by mechanism which was inadequate for every emergency, the risk of imprisoning men in compartments was too great, and the result often was that the doors were sometimes wedged or blocked so that they could not be unexpectedly shut.

Bull Dog.—A material used for lining puddling furnaces, comprising ferric and ferrous oxides, with silicon, and titanic acid. Its use was due to the inventor of the pig boiling process, Mr J. Hall, of Tipton, who substituted it for the old sand bottoms. Bull dog is calcined tap cinder, or the slag of the puddling furnaces calcined, by which part of the ferrous silicate is oxidised to the ferric state, which change renders it less fusible, and better qualified to supply oxygen to the charge. It is usually ground into a coarse powder before being introduced into the furnace. Bull dog has the following approximate composition:—Ferric oxide 63·90, Ferrous oxide 3·55, Silicon 15·75, Titanic acid 10·89, with traces of phosphorus, and sulphur.

Bulldozer.—A type of horizontal forging press, Fig. 86, Plate VII., used primarily for bending objects of large dimensions from plate, specially for the railway and wagon shops. It

fills for these, therefore, the place that is occupied by the drop hammer in general light forgings.

The work is pressed in cast dies, Fig. 87, Plate VII., by the movement of a ram or crosshead squeezing against a fixed abutment. The ram slides along a bed, to which it is fitted by a take-up strip. It is actuated by spur gears, either single or double, duplicated on each side of the machine, and imparting motion to two cranks connected to the ends of the crosshead. Steadiness of rotation is provided for by a flywheel. These machines are driven by belt, by a steam engine direct, or by electric motor. Some machines are made double ended, one end then having a shorter stroke than the other, specially for shearing, and turning short bends.

The place of the single geared bulldozers is in light work that requires little power and high speed. The rates in these vary from 30 to 40 strokes a minute. The double geared machines being more powerful are better for general service. Two sets of gearing furnished with these may be selected to run at slow, and quick speeds, as 8 or 10 strokes a minute, and 18 or 20 strokes respectively.

The bulldozer is started through a friction clutch, which avoids shocks, and being also under control, the movement of the crosshead can be arrested anywhere, to permit of testing the relations of the dies to the work when setting up. It can also be adjusted as a safety stop.

Some machines have a central crank only, but this permits cross working of the ram under pressure if the work lies to one side of the centre, and is unsuitable when two or more dies are arranged side by side for successive operations.

Bull Head.—Denotes the convex head of a rivet which has less than half the height of an ordinary convex headed rivet, coming between this and the flat head countersunk form. Also a form of rail.

Bull Nose Plane.—A small metal plane of the rebate type, in which the portion of the sole in front of the cutting edge is very short, and is connected with the body of the casting by being arched over the mouth, which gives it some resemblance to the nose of a bull. It is used for planing up to a shoulder.

Bullock Gear, or Horse Gear.—Denotes the method of driving well pumps, &c., by a bullock or horse walking in a circle, and turning a long pole connected to bevel wheels.

Bull Wheel.—The wheel of a planing machine which engages with the rack underneath the table, and drives it. It denotes a wheel of large diameter, to distinguish it from the usual pinion of small size which does not drive quite so smoothly.

Bunker.—The place occupied by the coal supply for a boiler.

Buoyancy.—The most important principle in hydrostatics is the Principle of Archimedes. The story goes that the famous Greek philosopher was asked by King Hieron how he might verify his suspicion that a fraudulent workman had used some silver in the making of a golden votive crown. While thinking about the matter in his bath, Archimedes suddenly discovered the principle which bears his name, and was so overjoyed that he leapt from the bath and, running naked through the streets, shouted "Eureka! Eureka!"—"I have found it, I have found it." The law is, that a body immersed in a fluid loses as much in weight as the weight of an equal volume of the fluid. Or, it may be stated, a body immersed in a fluid weighs less than it does *in vacuo* by the weight of the fluid displaced. Again, considering the upward pressure of the liquid, the resultant vertical thrust on the immersed body is exactly equal to the weight of the liquid which is displaced. This fact is illustrated by the following simple experiment. From one arm of a balance two brass cylinders are suspended, the upper one being hollow and the lower one solid, or, if hollow, watertight. The lower cylinder also fits exactly into the upper one. After being carefully balanced by placing weights in the other pan the lower cylinder is submerged in a beaker of water. The position of equilibrium is immediately lost, but on filling the upper cylinder with water the balance is again accurately restored. Evidently the apparent loss in weight observed when the lower cylinder was immersed is equal to the weight of the water in the upper cylinder; but this water is exactly equal to the bulk of the submerged cylinder. Thus it is proved that the brass

cylinder lost a weight equal to that of the water it displaced.

The question of the buoyancy of any body in any fluid is, then, a question of the relation between the specific gravity of the body on the one hand and that of the volume of the fluid displaced on the other. These three conditions follow as corollaries to the proposition of Archimedes. (*a*) If a solid remains immersed and stationary wherever placed in a liquid, then a cubic foot of the solid must weigh the same as a cubic foot of the liquid, otherwise the solid would rise or sink. (*b*) Similarly, if a cubic foot of the solid weighs less then a cubic foot of the liquid then the solid is forced to the surface by the upward pressure of the liquid; it would be impossible for it to remain immersed, for then the body would be stationary while displacing a greater weight than its own. In the case of a solid which floats with a portion only immersed the weight of the solid is equal to the weight of the water displaced by the submerged part. (*c*) Finally, if a cubic foot of a solid weighs more than a similar volume of the liquid the body must sink. The upward pressure is considered as acting through the **Centre of Buoyancy.** *See also* **Metacentre.**

A clear understanding of the principles mentioned above explains such apparent anomalies as the floating of coins, stones, and heavy metals on the surface of mercury. The specific gravity of mercury is 13·596, while that of silver is 10·6, lead 11·3, iron 7·8, and so on. On the other hand, with unity as the specific gravity of water, cork is ·24, poplar ·4, oak ·7 to 1·0, alcohol ·8, and ether ·73.

Buoyancy Chamber.—A chamber in a torpedo, the purpose of which is to maintain the buoyancy of the weapon. The propeller shaft passes through it. Its interior is reinforced against external pressure, and ballast in the bottom keeps the torpedo upright.

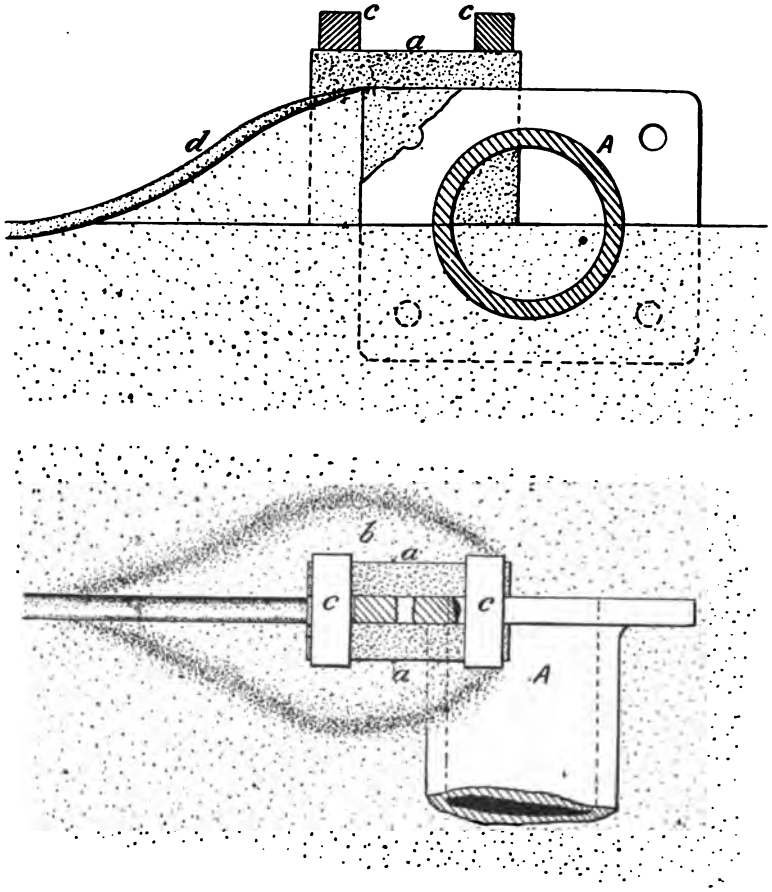


Fig. 88.—Burning on a Corner on a Flange.

Burden.—The charge of a blast furnace.

Burnett's Fluid.—A solution of chloride of zinc in water, and applied under pressure to the impregnation of timber, for its preservation. Two lb. of chloride of zinc to 10 gallons of water are used, and the pressure varies from 100 to 300 lb. per square inch. It renders timber

brittle, and spikes rust away badly in the timber so treated.

Burning On.—Denotes the practice of casting new metal on an earlier casting, effected generally either because the piece was imperfect in the manufacture, or has become damaged by accident. It is done by preparing a suitable mould, heating the casting and pouring a stream of melted metal over the surface, allowing a large quantity to flow away until the union of the old and new is completed by fusion.

The illustration, Fig. 88, shows the nature of the preparations required before the smallest piece can be burned on a casting. The mould is made in loam cake *a a*, and being set in place against the casting A, is secured by means of sand *b* and weights *c c*. A gutter or flow-off channel *d* is cut, coming away from the mould, for several hundredweights of metal may have to be run through before fusion of the old surface will take place. The moulder judges of this by poking a rod into the mould occasionally, and by bringing its end into contact with the surface of the old casting he is able to judge whether fusion has taken place. The metal is poured as hot and fluid as possible.

The policy of burning on is one often disputed. The correct view to take is whether the portion so added is a vital part of a casting on which safety depends. If so, the risk should not be taken. For though a sound weld can be made in this way, there is a risk, and the metal must be deteriorated in the process. In no case should such work be done surreptitiously, but under the sanction only of inspectors or principals with whom final responsibility rests.

Burnisher.—In the fitting shop it is a half-round file ground smoothly, with which by friction, a polish is imparted to metallic surfaces. In metal spinning it is a blunt instrument by which the sheet metal is turned over during its rotation.

Burnishing Die. — Many sheet-metal articles which are punched out in a blanking die need some finishing around the edges to give a good appearance. In the absence of subsequent machining operations a frequent practice is to use a burnishing die—similar to the blanking one—except that the hole tapers in the reverse direction. This being hardened and polished, imparts a smooth shining surface to the article when forced through, its edges becoming compressed and burnished.

Burnt Iron.—Cast iron which has lost its nature, *i.e.*, its crystalline characteristics, and has become red in colour, and rotten due to the absorption of oxygen.

Burnt Sand.—Foundry sand, that coming next the face of a casting receives the full intensity of the heat, and loses its coherence. It is then used for parting sand, or is thrown away.

Burnt Steel.—Forged carbon steel which has been overheated and become useless for cutting purposes, due probably to the partial oxidation. A smith generally cuts off the burnt end of a tool and re-forges, which is preferable to physicing it.

Burr.—A rough edge, or arris left round a hole, or along an edge that has been punched, or shorn, or otherwise cut. Also the actual piece or button punched through a plate.

Burring Reamer.—A special type of fluted reamer, having a large amount of taper, and a short body, which is used for removing the burr from the inside of pipes after cutting them off. The arris thrown up, if not reamered out, would interfere with the free flow of the liquids in the pipe.

Bursting Pressure.—The pressure which would rupture a hollow vessel. It is measured across the diameter. *See* **Cylinders—Strength of.**

Bus Bar.—*See* **Central Stations.**

Bush, Bushing. — A lining tube which forms the actual bearing of a shaft or spindle. Bushes are fitted for various reasons, generally to provide a better or more suitable material for the actual bearing than the metal in the main framing would afford. Thus iron is bushed with brass, gun-metal, phosphor bronze, white metal alloy, and in some cases with lignum vitæ. In each case the material is of an anti-friction character. Another reason is for readiness of renewal of worn parts. It is easier and cheaper to renew a few bushes than an entire framing, or than the shafts. As the holes in bush and framing are concentric, the renewal of bushes does not alter the centres, which might be the case if the frames had to be rebored for bushing, or for larger shafts.

Strictly speaking a bush is solid, *i.e.*, tubular and undivided, though the term bushing is often loosely applied to divided brasses. The term bushing also denotes the actual fitting and driving of bushes into their frames.

Bush Grinders. — *See* **Hole Grinding Machines.**

Butterfly Valves.—A pair of flap valves arranged back to back.

Buttress Thread.—*See* **Screw Threads.**

Butt Riveting.—*See* **Riveting.**

Butt Straps.—The straps or strips of metal that cover a butt riveted joint. *See* **Riveting.**

Butt Welded Tubes.—*See* **Tubes.**

Butt Welding.—*See* **Welding.**

By-pass.—A by-pass is a passage usually closed by a valve or controlled by the equivalent of a valve, which enables a gas or liquid to flow in an alternative channel.

One of the earliest forms of a by-pass is that embodied in the case of the water wheel. Placed at a point where a flow of water is held up by a natural or artificial dam, the water wheel affords a way of escape for the water; but when the flow of water to the wheel or turbine is stopped by the closing of the wheel sluice, the water is by-passed by way of an overflow weir, or by the original natural dam. The old river bed in this latter case forms the by-pass channel and the weir forms the valve, the opening of such valve being legitimately represented by the rise of water above the crown of the weir as it accumulates upon the shutting of the wheel sluice. Or quite as legitimately the mill lade may be considered as a by-pass for part of the original stream, the wheel sluice being then the by-pass valve.

One of the newest and most modern forms of by-pass is the electrical shunt, whereby a portion of an electrical current is allowed to pass by way of a secondary or branch wire, the ratio of the current which flows by way of the shunt or by-pass being inversely proportionate to the ratio of the resistances offered by each circuit.

Thus in the shunt field of a dynamo or motor the terminals of the machine are united by a wire in which are interposed the field windings of the machine. The field magnets are thus excited by the current generated in the machine itself, and a portion of such total current is utilised for this purpose through the shunt winding or by-pass, the valves of control being the field switch assisted by the resistance coils, which serve the part of a partially open valve by varying the relative resistance of the main circuit and of the field winding.

Between these extreme forms are many and various by-passes.

In the gas producer it is first necessary to blow the producer into an active state by means of a blower before it will produce gas fit for use in a gas engine. To enable this to be done, a valve is opened which allows the gas to escape to a flue which carries it away. This valve is a by-pass.

In steam engineering the waste gases from the boiler furnace are still possessed of heat that will serve to heat feed water in the so-called economiser. These gases may be led to the chimney either through the economiser or through a flue parallel with it, the direction of the gas being controlled by valves called dampers, which open the way either through the economiser or through the *by-pass* flue. A similar arrangement on the water feed pipe to the boiler enables the feed water to find its way to the boilers either by way of the economiser pipes or by a direct pipe. This direct pipe is a *by-pass*, and is controlled by shut-down valves so as to send the feed water by either channel.

The economiser supplies yet a third illustration of a *by-pass*, for in order that the pipes shall not be destroyed by the condensation upon them of the acid steam of the sulphurous furnace gases it is necessary that the entering water shall have a temperature of about 100° Fahr. Where otherwise absent this temperature is produced by allowing some of the feed water that has passed through the economiser to escape by a small pipe to the suction side of the feed pump. About a sixth of the total feed water is thus *by-passed* to the feed pump; the small pipe named is a *by-pass*, and the amount of water thus returned is controlled by a valve on the small pipe. A *by-pass* valve may thus be merely an ordinary valve. It acquires its name rather from its use than from its form.

In a blast furnace large volumes of gas are constantly being produced, and if for any

reason this is not needed, a *by-pass* valve must be opened to allow the gas to escape to the atmosphere. In the pumping of water it is very usual to pump the water over a ∩ pipe so as to ensure a head sufficient to supply to a given elevation. To prevent abnormal pressure the upper bend of the pipe may have a vertical pipe carried up a few feet higher and left open. Should the pumps raise an excess of water this pipe would become a *by-pass*, allowing the surplus to escape in safety and call attention to the waste. No valve is here necessary because the head serves the purpose of keeping the water at a sufficient pressure; but in the absence of a stand pipe the same effect may be approximated by means of a large air vessel combined with a loaded safety valve. Such a safety valve becomes a *by-pass* for the excess of pumped water. Indeed all safety valves for water or for steam are strictly *by-passes*. The atmospheric exhaust valve, which is made in the form of a large disc or mushroom valve, is placed on a branch from the main exhaust pipe between the engine and the condenser. When from any cause the vacuum ceases to be formed the engine would soon choke up with steam to boiler pressure, and the condenser might be burst by the pressure. But the atmospheric exhaust valve acts as an alternative route for the gas, or as a *by-pass* into the atmosphere by which the uncondensed steam can escape without danger. In the manufacture of gas it is necessary to turn the crude gas through various purifiers in different order as the degree of vitiation of the purifying agent is changed by use. The order of progression of the gas is changed by means of a variety of by-pass valves, one form of which consists of a box partly filled with water, above the surface of which extend pipes leading to different purifiers. By means of chambers projecting from the movable cover of this water box the projecting pipes can be joined up in different order so as to change the order of flow. The water in the box seals the lower edge of the upper chambers, and acts as the valve against such small pressures as are employed in gas manufacture.

In the same manufacture, where two scrubbers are employed in series, either of them may be cut out of the circuit by a *by-pass* and valve, which carries the gas round, instead of through, the scrubber.

In the Thwaite system of blast furnace gas purification, a constantly running fan, which propels gas from the main to the holder, is made to receive the gas back from the holder, as soon as this becomes full, by way of a *by-pass* which opens for the purpose as soon as the holder becomes full, as for example when the engine is stopped which is using the cleaned gas.

In sewerage work where it is not considered desirable to deal with storm water at the depositing tanks, or even to admit it into the main sewer, storm water weirs or *by-passes* are constructed to allow storm water to escape to a different outfall. Thus the old Fleet Ditch, which now is contained in the Farringdon Road sewer, empties itself into the London main drainage at Blackfriars, but in flood time it is by-passed by an overflow weir into the Thames under Blackfriars Bridge.

In water supply a rush of muddy water following upon heavy rain is often made to jump a gap into which it drops when flowing at less velocity and smaller volume. Such a jump forms a by-pass for muddy water which it is not desirable to impound.

In the compound locomotive, or the compound rolling mill engine, a *by-pass* valve is provided for the purpose of carrying steam from the boiler to the low pressure cylinder for periods of starting effort or special load, as when a heavy ingot is passing the rolls, or a heavy gradient is to be mounted. The high pressure cylinder and the reduction of pressure caused by it are thus *by-passed*.

In solid materials, as in the grinding of solids to powder, any material not sufficiently reduced in size may be caught by a sieve and compelled to return by a by-pass to be reground.

The *by-pass* in one form or other is very extensively employed, and the regulation of the proportion of material *passed by* may range from nothing to the whole according to circumstances. The examples cited will serve to illustrate some of the chief ends for which by-passes are applied. It will be observed that a by-pass may act wholly or not at all, as in the

atmospheric valve; more or less according to circumstances, as in the compound locomotive; or it may act suddenly, as in an automatic weir, to lower the obstruction of the weir several feet as soon as the water level above the weir has reached a given height. Such a by-pass as this possesses a selective power, and may be compared to the maximum cut-out of an electric switch-board which only acts when a maximum flow has been established. The weir only acts when a maximum head has been established. Electrical ammeters act by measurement of a by-passed current, the amount of the by-pass being fixed by ratio of the resistance of the main and the by-pass circuits.

As a final example of a by-pass may be cited the loaded valve which permits of the return to the oil container of such portion of the petroleum which is forced forward by a constant action pump, but is prevented from entering the vaporiser of an oil engine by the throttling action of the governed admission valve.

Bye-Product.—A bye-product is something unsought for that is produced in the process of making or manufacturing any desired article. Thus, to name a few, there is first coke, which is produced when gas is made. The coke is the solid, non-volatile portion of gas coal, and remains behind in the retort after the gas has been driven off.

Slag is a bye-product of the manufacture of pig iron, and consists of the earthy constituents of the iron ore combined with the lime flux and with some metallic iron, this last being of course an undesired waste.

Tar is a bye-product of the distillation of coal, due to imperfect gasification.

Carbonic acid gas is produced when certain organic matters are fermented, and is given off from fermenting flour in the production of dough, and from the fermentation of wort in the production of beers.

Gas is a bye-product in the production of coke when such coke is made for the special purpose of the blast furnace, and again carbonic oxide gas is a bye-product of such coke fuel when thus employed to smelt iron.

Carbonic oxide gas is also a primary product of coke when this coke is itself a bye-product, as when gas coke is employed as the raw material in the gas producer. Thus coke and gas may be products or bye-products according as they are the primary object sought, or only the unsought and unavoidable or "bye-product."

Bye-products have for ages been regarded as waste material, and have proved a nuisance to get rid of. Even though a valuable fuel, gas coke was often practically unsaleable, while gas tar was so plentiful as to be costly to dispose of. From time to time use has been found for certain bye-products, and in many cases they have become so valuable that they have risen in price to such a height as was compatible with their real value to those who had found a use for them. Thus the ammonia liquor of the gas works has been converted into sulphate of ammonia, and is a valuable manure for many crops. Gas tar has found a use in the manufacture of the aniline dyes and flavouring essences.

Coke made in London has become the fuel for Portland cement burning, and reached such a value that attempts are now made to use raw coal in its place. The thin tar from Pintsch Gas manufacture was such a nuisance on the Great Eastern Railway that a special arrangement was devised in order to burn it in the locomotives as a liquid fuel.

Since the bye-products of gas making have been found to be so valuable, there has been a growing tendency to find uses for other bye-products. When, however, the gas retort is seen producing gas as a primary and coke as a secondary product, and the coke oven is seen producing coke as a primary and gas as a secondary or bye-product, it is a matter of wonder that the bye-product of the coke oven should so long have been allowed to burn to unconsidered waste.

One can more readily understand the waste of a bye-product of which there is no production as a primary product. In basic slag there is a product of the iron furnace laden with phosphorus, and being ground, this forms a valuable manure.

Ordinary blast furnace slag has long been a seriously cumbersome bye-product, but the harder slags are broken up to make road metalling or railway ballast, and much slag

is made into bricks and artificial stone by the aid of cement.

For years no attempts were made to use the many millions of cubic feet of low calorific power gas turned out of the blast furnace.

In time the gas was used to heat the hot-blast stoves, and it became usual to burn it under the steam boilers in order to raise steam to drive the blowing engines of the furnace. But such use was very inefficient, and the efficiency of steam plant thus worked is not more than one-fifth that of plant worked by the use of the gas in gas engines (*see* **Blast Furnace Gas Engine**). Thwaite's discovery of the value of this bye-product has given us the large gas engine, and put in our hands millions of horse power if we would only use it in place of continuing to burn raw coal even within a stone's throw of blast furnaces.

One of the more recent applications of a "bye" or waste product is the use of iron cinder mixed with powdered aluminium in the Thermit Welding process. Here the extreme avidity of aluminium for oxygen, and the great excess of heat produced over what is produced by the oxidation of iron, are made useful in obtaining molten iron of high temperature by the simple ignition of the thermit mixture which is started by the aid of a pinch of barium peroxide. Heat is the product sought in the thermit process. A pure iron is one of the bye-products which is partially utilised by being allowed to adhere about the weld of a tramrail where this has been the work done by the heat. Another bye-product of the thermit process is the slag which is said to be carborundum, which carborundum produced in certain electrical furnaces was originally a bye-product, but found so useful as an abrasive that it soon became an object of primary manufacture.

The tendency of modern industrial development is towards the utilisation of bye-products not merely where these are obviously fitted for use, but where research and experiment are required to find such use. Thus the very existence of a waste product is to-day assumed to represent a gap in our knowledge, and there is assumed to be a use for that waste product, such use being considered as a proper object to be sought for, exactly as the astronomer sets himself to seek for a planet the existence of which is obviously required to fill a gap in the "scheme of things entire." The use of a waste product may thus result in a big fortune for a successful discoverer, or it may mean a small profit only. Again, the income derived from a successful employment of a waste may save an industry from extinction. The disposal of waste being costly, entailing large occupation of land in the case of blast furnace slag or the waste of a chemical works, or of carriage in the case of the huge domestic refuse of a large city, a profit is really earned if such waste can be disposed of at a reduced cost. City refuse tips form for long years a breeding-place for fever. The destructor which enables city refuse to destroy itself innocuously will save cartage to the tip and all the indirect loss due to disease, death, pauperism and degeneracy which a built upon city tip implies, while the bye-product of refuse destruction itself may be a sufficiency of steam power to convert the clinkered refuse into mortar or into artificial stone. The Horsfall Destructor Co. make an excellent hard blue brick from the clinker ground with lime, and treated in a steam oven.

Sanitary science at present demands refuse destruction even at an enhanced cost above the evil tip, and a narrow mind which only sees ledger costs may call this uncommercial. Broader minds see economies as above named even with unfavourable ledger balances, but it is always desirable to show if possible a ledger profit so as to gain the adherence of the narrow-minded section of the community who have no gift of imagination.

The class of waste and bye-products is much more extensive than some would be inclined to think.

Thus in quarrying chalk for cement manufacture in the lower Thames it was and still is largely the custom to get the chalk down to the water level only, leaving the whole underwater, and better, chalk untouched. J. Hoyle, however, introduced a system of under-water quarrying to a depth of 30 feet by means of working a vertical face of chalk by a piling engine with a falling chisel, picking up the cut chalk with a grab. By these means an

additional weight of chalk of many thousand tons per acre became a useful product where formerly left waste or unquarried.

Perhaps no more sinful, culpable, and wilful waste takes place than in coal mining, where by bad mining huge pillars of coal are left ungot, and large amounts of small coal are left in the mine. Such small coal is convertible into the best of coke in the bye-product coke oven, which may thus use one waste product in being arranged to save the hitherto bye-products gas and tar oils. When not suitable for coke, such waste small coal may be briquetted into valuable lump fuel, which will bear hot climate storage better than natural coal owing to being impervious to air or water.

Hydrochloric acid, now a valuable article of commerce, was once a wasted bye-product that was often allowed to run to waste in the canals, to the destruction of boats, and of the boilers in the factories which used the canals as the source of feed water. Sulphur is largely recovered as a bye-product of lead-smelting, pyritical ore roasting, and from chemical wastes. Indeed there are few industries where waste products have not been brought into payable use, or are not capable of such beneficial use; and whenever a new works is started, whether to produce already known products or to deal with some new invention, the designer should, and is expected to make it his aim to produce no ultimate wastes, but so to order his manufacture that everything which is brought into the place shall be sold out of it so far as practicable. We are still far from such complete utilisation in many industries, but it is the goal to be kept ever before us. It is of course not necessary that a manufacturer should convert his own wastes into their ultimate selling form. For example, a gas works sells its bye-product, tar, to the tar distiller. At some works where coke can be sold locally, and tar must be carried to a distance, the tar may be partially burned under the retorts so as to save the coke for ready sale. Local conditions will determine the course of procedure. Fortunately there is almost always some procedure which is better than absolute waste.

C

Cab.—The covering over the footplate of a locomotive which affords protection to the various fittings on the boiler front, and to the driver and stoker. It is made of $\frac{3}{16}$-in. steel plate, stiffened around the edges with beading and angle iron, and two spectacle glasses are fixed in brass frames at a height suitable for observation. National differences are noticeable in the cabs of English and foreign locomotives, the former being usually less of a covering than is the custom in America and on the Continent.

Cabinet, Cabinet Legs.—The cupboard form of base, or pillar which is used to support the upper portions of many machine tools, is utilised for the storage of the small tools and appliances and gears belonging to the machines. The general substitution of the box type of machine framing for the plain ribbed design has been favourable to the cabinet shape, so that the latter becomes the extension and utilisation of the former. It is seen in the general substitution of cabinet or cupboard legs for lathes in place of the old **A** shape of legs, in the fitting up of the heads of gear-cutting machines with shelves or pigeon holes for change gears, in the provision of shelves in the pillars of plain and universal horizontal spindle milling machines, &c., &c.

The hollow framing is also utilised for the enclosure of gears, in some vertical milling machines, provision being made for oiling them from without, through tubes; in the enclosure of the nest type of change gears of lathes, for the concealment of the counterbalance weights, and chains of slotting machine heads, &c. The interior also often provides a reservoir for the lubricant of the cutters, which is pumped therefrom. Examples of these kinds will be found in machine tools illustrated in these volumes.

Cable.—A cable is either made of hempen rope, or of link chain, or of twisted wire.

A cable is a tension organ only, and much of its virtue lies in its flexibility, so that it can be bent round pulleys and drums. It can be used to transmit power like a belt. The cables have given rise to an immense number of mechanisms employed in their operation. The employment of cables is vastly greater than was the case a few years since. Their development has been due to several things, as the growth of cable ways for the transportation of goods, the extensive substitution of wire ropes for those of hemp, and for link chains, and the development of electric transmission for light and power. The methods of manufacture of cables will be described under **Ropes**, and **Wire Ropes**.

Cable Laid Rope.—A hempen rope in which hemp fibres are laid up in a right-handed direction into yarns, those are then laid up left-handed into strands. These strands are laid up right-handed into a hawser, and three hawsers laid up left-handed form a cable.

Cableways.—A distinction is sometimes made between cableways and ropeways, the first having no intermediate supports. The present article includes both. The details of cableways include the standards or pillars for carrying the ropes, at the terminal stations, and at intermediate points, the driving gear and pulleys, the supporting pulleys, tension gear, the ropes, for carrying the load and hauling the carriages, and the carriages themselves. All these details are very diversified in different installations, according to situation, scope of the cableway, loads, &c.

The standards are either of timber, cast iron, or steel; when the former they are bolted up and strutted with diagonals to resist the pulling strains. Steel framings are usually of angle at the corners, stiffened with flat bracings. The distance apart of the towers usually ranges from 100 to 200 feet, but exceptional circumstances may demand greater spans. The driving pulleys, actuated by an engine or motor on the ground below, grip the hauling ropes and move them in one direction or the other. Tension devices are provided to take up the slack of the ropes as far as possible, the driving pulleys being held in sliding frames pulled back by weights. On the intermediate towers sheaves

are placed to carry the ropes. Tension arrangements are sometimes provided at these stations, the carrying ropes being parted, and one end pulled on by a counterweight, the space between the ropes being bridged by solid rails. A somewhat similar method is employed for changing the direction of motion to right or other angles, the ropes running around the angle of a special tower. The carriages which run upon the carrying rope are of many varied forms, according to the class of goods to be handled. Fig. 89 gives five examples of how articles are carried, A and B being skips to hold any kind of loose materials, with or without tipping. Numerous variations on these designs are made, as triangular, round bottomed, open-sided, or simply flat platform shape. C is a basket, hooked up to the hanger; D a method of gripping casks, balks, &c.; E hooks for attachment to casks. Ordinary chain slings are also commonly employed for sacks, and curved hooks for bars of iron, &c. These carriages run upon two wheels, and a friction-grip attachment is used to grip the hauling rope, which may be either above or below the carrying rope.

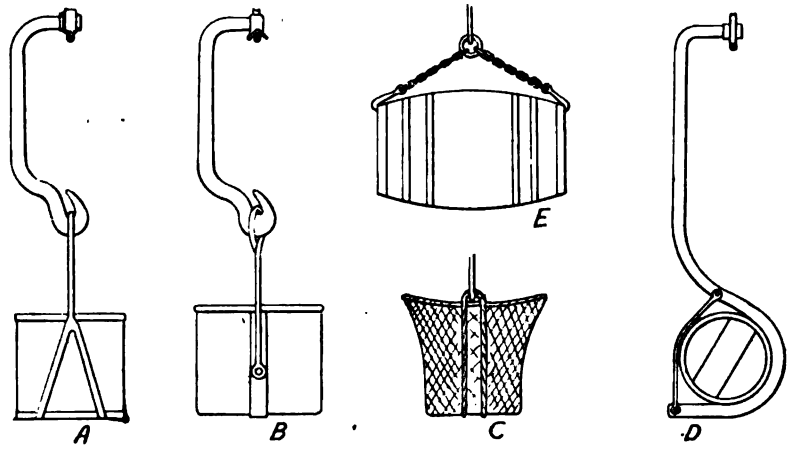


Fig. 89.—Buckets, &c., for Cableways.

The carriage shown in Fig. 90 is for the Henderson cableway; it provides means for hoisting the load, as well as travelling it along. There are four ropes, A, B, C, and D. A is the main one, on which the carriage runs by three wheels, E, E, pivoted on the ends of a lever, and F, having a bearing in the frame sides, thus allowing of accommodation to the varying curves of the rope as it sags. The hoisting rope D runs from the station terminal, over the pulley G, so lifting the snatch block below. The hauling or travelling rope C is attached to each end of the carriage, as at J, at the bottom portion, a guide pulley C being fitted to steady the rope at the top. An ingenious method is adopted for absorbing the slack of rope C, which has to be paid out while the carriage is travelling, the weight of C causing it to sag very excessively. An extra "button" rope B is laid above the main cable A, and has on it four or more large round buttons, fixed at equidistant positions along its length, these buttons being of varying sizes, becoming smaller as they get further from the driving end of the cable. The first (or smallest button) engages in a loop in the carrier H, and raises this, so hoisting the cable C simultaneously. The next button then intercepts another loop, and hitches up the cable again, thus causing it to present a festoon-like appearance, until it is brought into use by hauling the load up. *a* is a small guide pulley for rope C. A combined type of engine is employed for actuating this design of cableway, comprising both hoisting drum and travelling wheel on the same shaft.

A recent electric cableway which is of special interest, is that by which the great Zambesi bridge was erected. It is interesting from its maximum height, 460 feet above the river, being the highest bridge in the world, and its span of about 650 feet, but more so from the self-adjusting tension arrangement by means of counterweighted sheer legs, or jib pivoted at one end, which automatically adjusts its position to that of the load being traversed.

The conveyor trolly (Blondin), as it was termed by the men, was suspended by two wheels from a cable receiving current from a

copper conductor, by which device the employment of running ropes and fall carriers was avoided. The cables were suspended at one end from a rigid steel tower, and at the other to the hinged sheers, the bearing for the pivot of which was laid in concrete. The sheers were inclined in a direction away from the chain, and counterweighted against the pull of the cable by sixty tons of weights. The operation was as follows:—

The conveyor was suspended from a wire rope cable by means of two trolly wheels, and carried an attendant in a cage. The framing carried an electric motor, a driver's chair, and two

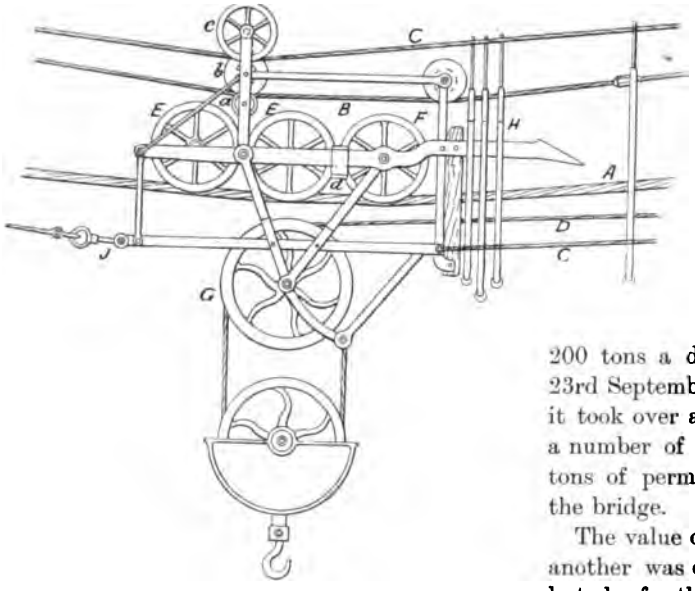


Fig. 90.—Henderson Carriage.

drums, motor driven, and having the hoisting ropes wound round them. A pinion on the end of the motor shaft engaged with either one of two spur wheels on the side of the carriage. The shaft of one of these wheels carried a pinion gearing with teeth on the two travelling wheels. The other wheel operated through the lifting drum, on which the ropes attached to the skips were wound. Each drum being controlled independently by levers, the driver was able to lift, lower, and travel.

When the conveyor travelled from either end support over the stream, the hinged sheer assumed a steeper position in obedience to the strain on the rope. As it returned towards either bank, the counterweight dropped, pulling the cable into a position of less curvature, and so helping the work of the motor in pulling the conveyor up the rope. To get the cable across, a rocket was first shot over the chasm, attached to the end of a cord. The cord was then used for hauling a wire across, and this was utilised to pull a small rope over. By means of the latter a small steel carrier fitted with clips at the bottom was used with the cable attached to the clips, and this was hauled over with a winch by a rope.

The conveyor weighed 5 tons, and its maximum load was 10 tons. The cable consisted of six strands, each of nineteen steel wires 0·125 in diameter with a hemp core, the circumference being 8·5 in., and the weight about 5 tons. The length was 175 feet, and the breaking stress 275 tons. The capacity of the conveyor was equal to about 200 tons a day. In the five weeks between 23rd September and the end of October 1904, it took over a locomotive and tender in parts, a number of railway trucks in pieces, and 800 tons of permanent way material required for the bridge.



The value of the conveyor was so great that another was constructed, partly as a stand by, but also for the extension of the line northwards from the Falls. The opportunity was taken of effecting some improvements in the new one. Weight was lessened by the substitution of plated work for castings. But the principal difference made was in the tyres of the driving wheels, which were rapidly cut out by the rope, so that they had to be renewed about every three weeks. The cast-iron tyres of the driving wheels were at first made of soft metal, with the idea of reducing the wear on the rope to a minimum. They wore too rapidly, the strands of the rope cutting into them; the screws were put in through the tyres, cast in halves into the wheel centres, their frequent renewal was a tedious operation, besides the expense, £13 per

pair of tyres. In the new design the tyres were made of rather harder material and thicker in the head, and the bolts were put in from the side, so that renewals are effected readily.

Cadmium (Cd 112·4) is a white, moderately soft, malleable and ductile metal somewhat resembling tin. Its specific gravity is 8·6, and its melting point 315° C. Cadmium is found in zinc ores (which contain from 1 to 3 per cent. of it), from which it is separated by heat; being more volatile than zinc it comes off earlier and is immediately condensed. When exposed to the air this metal tarnishes slightly; it forms a brown oxide, CdO, when heated in air; and dissolves in acids, and forms colourless salts. The sulphide, CdS, occurs naturally in Renfrewshire under the name of greenockite, and is known to the artist as Cadmium Yellow. Cadmium forms several alloys whose chief characteristic is their low melting point. It is alloyed with silver in electroplating.

Cage. — Any enclosing framework for the reception of something in transit. Generally it is understood to apply to the cage of a colliery, or to that of an overhead travelling crane, or a conveyor for wire rope transit.

The cage for an overhead travelling crane, Fig. 91, is designed so that the attendant shall have a

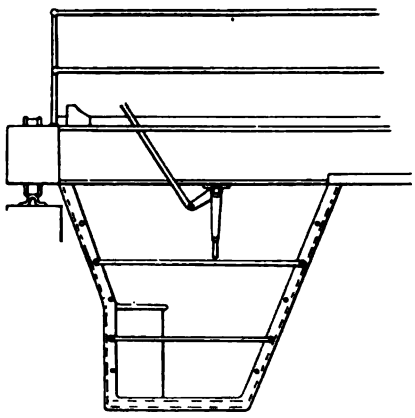


Fig. 91.—Cage for Common Travellers.

full view of the operations going on in the shop area below. It is built of angle iron, and flat bracing, so being practically open for observation all round. A seat is provided, and all operating levers are brought within reach of the driver's hands. In electrical cranes the various controllers are located in the cage, Fig. 92.

This is an alternative to the older method of placing the driver on the crab on the traveller, adopted first in hand, and then in steam cranes.

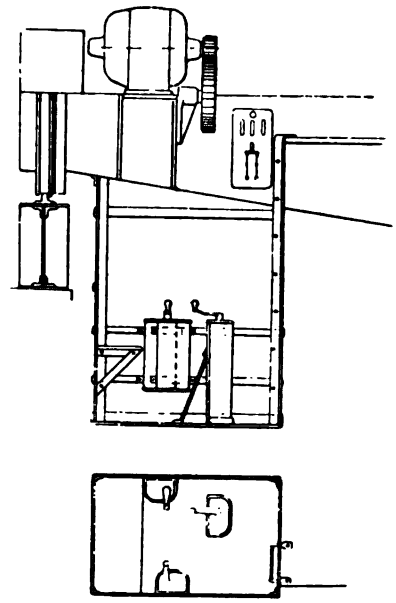


Fig. 92.—Cage containing Controllers for Electric Travellers.

It was an inconvenient position for making observations of the work going on below, and much shouting was necessary. When cotton ropes came into use, the cage at the end was commonly adopted, and since the electric drive has become so popular that position is practically universally adopted.

A cage is also the casing in which a ball valve is confined, hence often termed a cage valve.

Cage (Mining).—The cage is the apparatus, made in iron or steel, on which men and minerals are carried when being drawn up or let down the shaft. It consists of a platform, with rails or guides for the wheels of the mine wagons, and some form of catch at each end to prevent the wagons from running off; sides which support the platform, and a roof, usually with its two sides sloping at an acute angle; and above the roof, attached to the main pillars of the sides are the chains which support the cage when it is being drawn up and down. There are usually four chains, sometimes six if it is a long cage,

connected to the four corners, the four being united in a ring over the centre of the cage, with which the shackle at the end of the winding rope engages. The sides of the cage consist of supports for the platform and roof, with longitudinal members connecting them, and usually the lower halves of the sides are covered with iron plates.

Under the platform of the cage at each landing stage there are four props, which project out into the shaft, and the cage is supported by them when at rest and when not held by the winding rope. Those at the surface are withdrawn by the banksman by means of a lever, the cage being lifted temporarily to release them when the cage descends.

Cages are made single, double, and treble decked, and the platforms are arranged to carry two, three, or four mine wagons. The sizes of the mine wagons vary in every district, and the sectional area of the shaft also varies, hence the differences in the arrangements of the cages. A very common arrangement is a cage with two decks, each deck carrying two wagons. The outsides of the cages, on the side nearest the shaft wall, carry shoes which engage with the guides provided to steady them as they ascend and descend. In old and shallow mines the guides are usually of wood, in the more modern mines they are of wire rope, the shoes being replaced by sockets or bearings in which the guides run. Several attempts have been made to design cages that will stop automatically in the shaft, if the rope breaks, but so far none have come into general use.

In the older metalliferous mines, in which the shafts are at an incline, and the inclination frequently changing, as the lead of the ore changes, what are called "Skips" are employed. They are cages made to run on the inclines, and to follow the variations of the shaft. Practically they are boxes on wheels, their longitudinal section being rhomboidal. Men are not allowed to ride in them, though they often do so, in preference to coming up by the tedious man engine, or tiring ladders. In later metalliferous mines, the shafts are vertical, and the ordinary shaped cage can be employed.

There is another apparatus that is employed during sinking operations, called the "bowk," consisting of an iron, or steel cylindrical tub, suspended from the winding rope, by chains. Men go up and down the sinking pit in the "bowk," and the dirt, stones, rocks, &c., are brought up by it. It had one serious drawback till lately, it spun round like a top in ascending and descending. With the advent of the locked coil winding rope this has been stopped.

Caisson.—A word derived from the French *Caisse*, a box. It signifies literally a casing which is floated over an area to be covered by a subaqueous foundation; or sunk on, or into the solid ground beneath. As it sinks, the solid masonry or concrete is built up within it, sinking and building proceeding until the required depth and height are reached. This simple statement of an operation does not give any account of the many variations which must be made to suit varying conditions.

The first distinction to be noted is that between permanent, and temporary caissons. Both kinds occur in timber, and in iron and steel work. The first remains in place perpetually. The second is used as a temporary protection and environment for the work of pier construction.

The terms cofferdam and caisson are sometimes used loosely, as when cofferdam is applied to the temporary or movable portion of a caisson, which it resembles in regard to its function, but not strictly in its details of construction, piling being properly the essential in a cofferdam.

Timber as a material for caissons was once more common than it is now. But the choice is largely a question of location. It is seldom used in England, but is common in the United States. In the construction of the Williamsburg Bridge, just completed over the East River, New York, timber caissons were employed.

Forms of Caissons.—A form of caisson used in America has sides (temporary) which are readily detached from the bottom (permanent), so effecting a great saving in timber, besides which, the water-way is not encroached upon more than is necessary beyond the masonry. Such caissons, being first built on land, are floated out and sunk, and the masonry built on the timber floor, after which the sides are

detached by special contrivances, and floated off, to be again used on other foundations.

In caissons of steel or iron the only difference in construction is that the permanent one, lying deeper, is built of thicker materials, and more extensively braced. And if it is designed to be sunk by penetration, a cutting edge is provided around its lower end.

Caisson Sinking.—Caissons, whether made in wood or metal, are sunk by different methods, depending on the nature of the soil, and the force of the stream. In suitable soil they are mostly weighted to cause the cutting edge just mentioned to penetrate. To permit of this the soil is cut away by men from the interior. When rock occurs and large boulders, blasting has to be done, holes being bored by rock drills for the reception of small charges of dynamite. A hydraulic jet is used with advantage to clear out mud; hard clay must be excavated with pick and shovel. Caissons without knife edges are sometimes sunk on prepared beds. Thus, rocky bottoms may be levelled up with stones and gravel. In such work divers have to be employed.

Caissons are sunk by the guidance of piles driven alongside. Or they are lowered by means of screws supported on temporary timber staging flanking the caisson.

The excavations, and the masonry or concrete work done inside caissons being effected in the dry, there are two methods adopted, one being to work in the open, the water being pumped out, the other to work in a chamber below, roofed over, watertight and supplied with compressed air. Connection is made above the water level through the medium of air locks.

Air Locks.—An air lock is a chamber provided in a caisson, for the safe ascent and descent of men, and for the removal of excavated materials, and for supplying materials to the men. Designs vary. The lock is placed in the shaft that goes down to the bottom of the caisson, and is closed above and below by sliding doors operated by power, or by hand. During the ascent of a skip, or cage, the upper door is closed, and when the lock is entered the lower door is closed and the compressed air is allowed to escape. The upper door is then opened, and the skip or cage completes its journey. The pressure of the air in the caisson and air locks being equal to that corresponding with the depth of submergence is the reason why air locks are necessary.

Caissons have to be built to withstand great external pressure, which increases with the depth of sinking. They must be also water and air tight at all joints, which renders the task of construction difficult. Many accidents have occurred in consequence of faulty design and workmanship. In some instances the caisson is allowed to be filled with water every tide, because the force of the water would be too great, and crush it. In the case of the Inchgarvie piers of the Forth Bridge, the volume of water that had to be pumped out at every tide was 250,000 gallons in one case, and 340,000 gallons in the other.

The Forth Bridge Caissons.—There are few romances in engineers' work more thrilling than that of laying foundations under water. The vast arms of steel of the Forth Bridge which stretch far out to grasp each other, depend for their stability on the piers sunk nearly 200 feet below. Travellers who never cease to admire those immense ribs of steel scarce give a thought to the foundations which are equally wonderful; foundations, too, which swallowed up £800,000, the cost of a big liner. Enormous quantities of material that will never again be seen by the eye of man are buried down in that estuary. There lie 3,174 tons of iron and steel, and 43,809 cubic yards of concrete. In the piers, the tops only of which rise out of the water, there are 147,386 cubic feet of granite used, and 24,510 yards of rubble thrown in behind the solid granite as hearting. Add to this the labours of armies of men who worked during over two years in the river bed, and thus more than three-quarters of a million sterling went in buried work before the great bridge could be built.

The men toiled in the great caissons in electrically-lighted chambers, burrowing in prehistoric clay, and among glacial boulders illuminated by half a dozen 2,000 candle power lamps. Often between twenty and thirty men delved there, breathing an atmosphere twice as dense as that above, but the density of which prevented an inrush of water.

Nearly every day while the work of the Forth Bridge was in progress new difficulties and dangers were met and had to be overcome. To fix huge caissons, some of them weighing between 3,000 and 4,000 tons, exactly in place, in a turbulent estuary, to keep them upright as they sunk on an uneven bed, taking precautions to prevent sudden subsidences in the clay at low tide which would have crushed the men in the chamber beneath, to permit ingress and egress of the men to and from the chamber without permitting the air pressure to lessen, all these called for the exercise of the highest qualities of coolness and foresight and resource, in combination with engineering skill. Twelve great circular piers were thus built in caissons in the estuary of the Forth.

Take the Inchgarvie pier, one of the caissons used for which is shown in Fig. 93. The foundations were built within two such caissons 70 feet in diameter, and about 60 feet deep. Seven feet from the bottom of each caisson there was a roof with doorways in it, leaving between this roof and the bottom edge a chamber 70 feet in diameter and 7 feet high. In this the men worked, cutting and blasting the rock in the river bed in readiness to receive the masonry of the pier. As they dug away the rock, the caisson cut its way down by its sharp knife edge. The men went down to their work through a tube 3 ft. 6 in. in diameter, containing a ladder. To prevent the relief of the air pressure, often as much as 35 lb. on the square inch, the air lock received the men, and it was closed by an india-rubber-faced door in order to allow the pressure to increase in the lock to that below, before opening the door leading directly into the tube. There were two similar tubes up which the excavated stuff was lifted, and down which concrete was passed for filling the chamber after the excavations were finished.

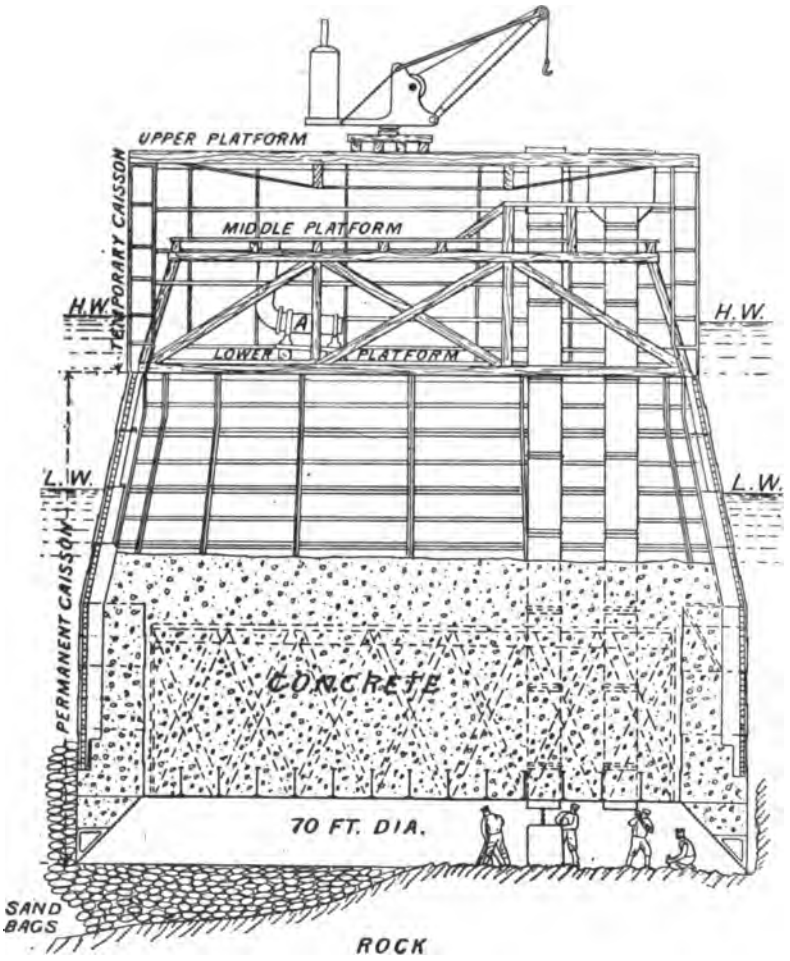


Fig. 93.—Inchgarvie Caisson, Forth Bridge. (Messrs Sir W. Arrol & Co., Ltd.)

At Queensferry the deep mud gave far more trouble than the hard rock at Inchgarvie had caused, and in fact it resulted in a loss of life. Once a caisson sunk 7 feet into the mud. At another time several of the men were buried up to their chins in mud. On one

occasion the caisson stuck in the mud on one side, and became tilted up and filled with water. Three months were occupied in raising it and pumping it dry, and then it collapsed and killed two men. Two years were occupied in building this pier. One of the Queensferry caissons is shown in Fig. 94.

The Williamsburg Bridge.—The caissons of the Williamsburg Bridge are of timber, carried down to solid rock. One of these under the Brooklyn Tower has a height of 53 ft., and measures 63 ft. by 79 ft. It contains about 74,700 cub. ft. of pine timber, weighing about 1,867 tons, and 98 tons of steel. Its top is about 47 ft. below high water. It contains about 7,240 tons of concrete, and is of the type containing a working chamber with air locks. The construction was as follows:—

The outside vertical walls are made with solid timber, planed, and fastened together with 1-in. bolts driven through $\frac{7}{8}$-in. holes, and the joints caulked with oakum and secured with pitch. They are sheathed outside with a course of vertical and a course of diagonal tongued and grooved planks; vertical timbers are bolted inside.

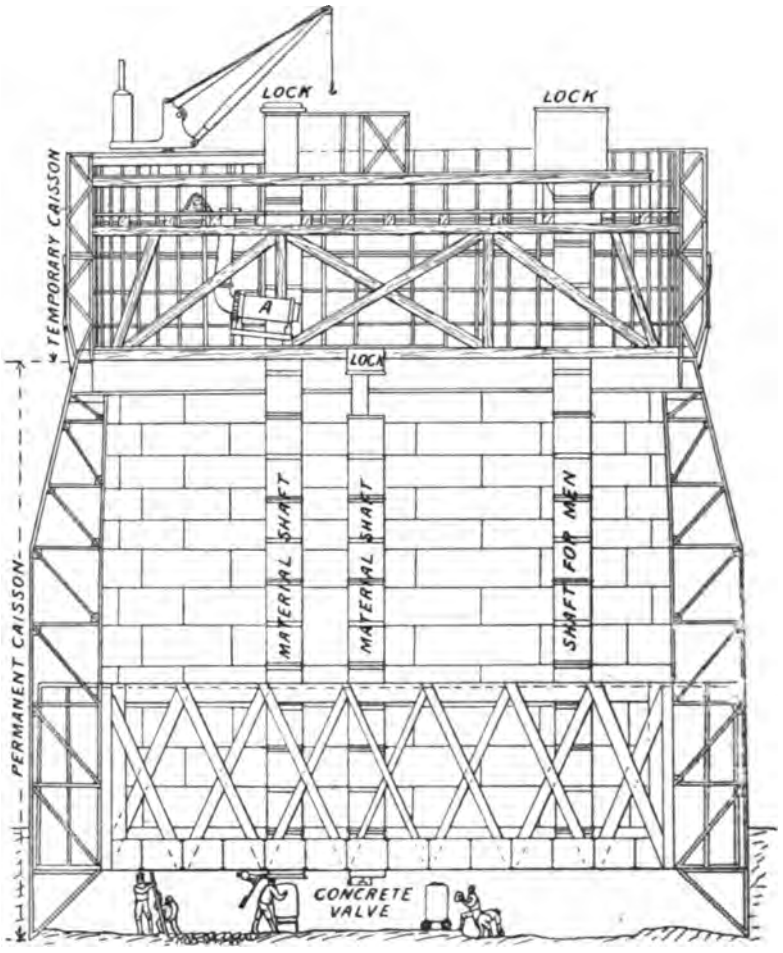


Fig. 94.—Queensferry Caisson, Forth Bridge. (Messrs Sir W. Arrol & Co., Ltd.)

The working chamber, $7\frac{1}{2}$ ft. high, is roofed over with a bottom course of 12-in. by 12-in. timbers, caulked and sheathed on the underside with 3-in. tongued and grooved planks. Two coursed thicknesses of 3-in. by 12-in. tongued and grooved planks are laid diagonally on top, and an upper course of 12-in. by 12-in. timber. The chamber is stiffened by transverse bulkheads of solid timber 30 in. thick, and by two transverse and longitudinal struts. Above the roof, the caisson is braced with longitudinal and transverse timbers 12 in. by 12 in., and variously cross braced. The cutting edges of the caisson are of oak timber, shod with a 6-in. by 8-in. angle, and stiffened by knee braces. The corners are protected by 40-in. by $\frac{1}{4}$-in. bent vertical plates.

Over this came a temporary caisson, or cofferdam which always reached above the level of the water, and permitted of the construction of the masonry independently of the position of the cutting edges. It was constructed in a similar manner to the caisson,

with main timber sheathings, bracings, &c., and was connected to the caisson by vertical rods with jaws and hooks engaging wedges, which, being driven out under water, relieved the temporary caisson, so that it would float up. This temporary section contained about 29,000 cub. ft. of timber, and 33 tons of iron and steel. The caisson was provided with seven air shafts 3 ft. in diameter, with air locks, six 4-in. sand pipes, one 6-in. air pressure pipe, three 5-in. water pipes, and two 1¼-in. conduit pipes for electric wires.

The air locks were of different types. In one of the shafts for the men there were three diaphragms, either of the lower ones being used for the bottom of the lock, making it 8 ft. deep for day service, and 24 ft. when shifts were being changed, to economise time. It contained an elevator cage for eighteen men, and an emergency ladder. In others for materials there were variations in design. Each had a hoisting engine outside, operated by a lever passing within the lock, operated by two attendants within, who also received the buckets of material from below, and tipped it into a chute, whence it was discharged into a scow alongside. There were variations in the design of these air locks. Another set of locks was used for the deposition of concrete from above.

The Nebraska Bridge.—The Nebraska City Bridge was built on timber caissons 54 ft. long, 24 ft. wide, and 15 ft. high. Two caissons cost £1,160 for material, and £1,030 for labour upon them before they were sunk. To sink them cost another £2,460. Including the concrete filling and other matters these two cost £10,000, which worked out to about £3. 16s. for every cubic yard which they occupied.

The Tower Bridge.—The caissons of the Tower Bridge are in rows, four in number on the north and south faces of each pier, joined at each end by a pair of triangular-shaped caissons, the shape thus approximating roughly to the angle of the cutwaters lying beyond them. A space of 2 ft. 6 in. was left between adjacent caissons to allow room for the workmen. A rectangular space of 124 ft. 6 in. by 34 ft. is enclosed by the caissons.

Before the caissons could be sunk it was necessary to drive piling to receive timbers, upon which to erect the caissons at a height a little above low water level, over the positions which they were to occupy. The timbers being subsequently removed, the caissons were lowered into place. This was done by means of screwed lowering rods, four in number, one being connected to each corner joist. Their nuts bore on trussed timber beams above, placed over the caisson and having their ends resting on the flanking timber stagings. The lowering could thus be done gradually, without risk of any tilting up occurring, such as happened to the Queensferry caisson at the Forth Bridge.

The superstructure of the piers erected over the caisson area is composed of concrete below the river bed, and the upper parts of Gault brick-work in cement, faced with Cornish granite. As the caissons had to be sunk to a depth of about 19 ft. below the river bed, it was necessary to employ temporary caissons above the permanent ones, in order to permit of carrying out the excavations. And while the permanent caissons were 19 ft. deep, the temporary ones were 38 ft. in height. Being built in lengths of from 10 ft. 6 in. to 12 ft. and added as the caisson sunk, the joints were made watertight with indiarubber. The plate thicknesses ranged from ½ in. at the bottom of the permanent caisson, to ¼ in. at the top of the temporary one. A cutting edge of rolled steel was riveted to the bottom ring, standing out beyond the cylinder to diminish friction, and being stiffened above by vertical joists supported by timbers.

Gradually the caissons were sunk at varying rates, cutting their passage into the stiff London clay until at depths of 4 ft. or 5 ft. the water could be pumped from the interior without fear of the river finding its way beneath the cutting edge. Priestman grabs excavated to a depth of 5 ft. or 6 ft. below the edges, divers excavating the material round the sides, and shovelling it towards the centre. As the work progressed, the timber frames were loaded with many tons of kentledge, as much as 274 tons in one case, until the required depth of 19 ft. below the river bed was reached. The 2 ft. 6 in. spaces between the caissons were filled up with piling. As the area covered by the caissons was not sufficient for the stability of the piers, at the limitation set of 4 tons per

square foot, sloping excavations were carried out 5 ft. beyond the edges, and 7 ft. below them, and the concrete filling was carried into these spaces. This is an example of a caisson open above, and into which the tide was allowed access. The divers then worked within at certain stages until the masonry or concrete arrived at a stage at which the water could be pumped out, and work be finished in the dry.

In deep caissons having closed working chambers, the pressure of the compressed air is felt painfully in the drums of the ears: pains in the limbs follow, which if the work is too long continued, result in paralysis. In making the foundations of the great St Louis Bridge in America, 119 workmen out of 600 were thus attacked, sixteen of whom died. It is desirable therefore to employ men who have become seasoned to this kind of work. Terrible accidents have sometimes happened to men working in caissons. One occurred in the bed of the Neva at St Petersburg in 1876. A caisson sunk suddenly, and seven men then imprisoned in the working chamber were smothered. The next year an air lock gave way, and nine men were blown out and killed, as by an explosion of gunpowder, and twenty others were smothered in the mud. Thirteen months elapsed before the chamber of death could be opened out again.

When working in deep caissons, men get paid at higher rates, and work shorter shifts the deeper they go. On the Williamsburg Bridge, they received at the beginning 2·50 dollars per eight hours' work; when they had got 107 ft. below water level they received 3·75 dollars for two forty-five minutes' shifts. Hot dressing-rooms, hot baths, and plenty of hot coffee were provided. After a depth of 60 ft. had been reached, steam elevators were provided in the main shafts to save the men the exertion of climbing.

There is another large group of caissons not used for foundations. They will be found noticed under **Dock Caissons**, and **Floating Docks**.

Calcining.—Calcining, or roasting, is one of the processes through which some of the metallic ores pass, either for the purpose of producing a directly marketable substance, or as a preliminary to other processes. It is employed to drive off some substance contained in the ore that is more volatile than the remainder, the absence of the substance driven off increasing the value of the ore by increasing the percentage of the metal in the residue.

The commonest instance of calcining is the ordinary lime kiln, in which the carbonic acid contained in the limestone is driven off by heat, quicklime being produced. Clay ironstone also, which is a carbonate, has the carbonic acid driven off by calcining, magnetic oxide of iron remaining. The original ore contains only about 48 per cent. of iron, while after calcining the residue contains about 72 per cent. Iron ores containing sulphur are calcined to drive off the sulphur, before the ore is fed to the blast furnace. Gypsum, when heated, has the water that is chemically combined with it driven off, and becomes plaster of paris.

In other cases the substance that it is required to preserve is driven off by heat, the fumes which are formed being afterwards condensed in flues specially arranged to catch them. This is done with arsenic. Copper ores containing arsenic are calcined, the arsenic being driven off, and condensed as described, while the remainder of the ore is treated in the usual way. Gold and tin ores are sometimes calcined, to separate them from the sulphides, and sulphurcenides in the case of gold, and to separate the tin from wolfram.

The methods of calcining are various. In some cases the ore is merely stacked up in heaps, with fuel where it is necessary, and set fire to. Some ores contain sufficient carbon to burn without fuel. In the majority of cases, however, in modern practice, the ore is calcined in some form of furnace. There are several types of furnace designed specially for this purpose on the market. A favourite arrangement consists of a cylinder, revolving on wheels which are driven by gearing, or by friction, from outside. The ore passes through the cylinder slowly, and is exposed to hot gases from a furnace fixed at one end, the volatile products it is wished to drive off passing either up a chimney arranged to receive them, or into flues where they are condensed, the residue of the ore passing into receptacles, from which they go to the smelting furnace.

Calcium (Ca 40·1) is a hard, whitish, ductile and malleable metal with a specific gravity of 1·57. When heated in air it burns with a brilliant white light, and when placed in water it liberates the hydrogen and forms CaO. It rapidly tarnishes yellow when exposed to air and hence is kept in naphtha. The pure metal is obtained by the electrolysis of chloride of calcium, $CaCl_2$. Calcium is found in great abundance in combination with other substances. The carbonate, $CaCo_3$, is the chief constituent of limestone, chalk, marble; the sulphate, $CaSo_4$, occurs in gypsum, selenite, and plaster of paris; calcium fluoride, CaF_2, in fluor spar; and calcium phosphate, $Ca_3(Po_4)_2$, in bones. The presence of the sulphate or the carbonate in water, cause in the first case permanent, and in the second temporary hardness. Boiling does not produce the precipitation of $CaSo_4$, but the carbonate is decomposed into carbonic acid which escapes, and chalk which is precipitated. *See* **Carbonate of Lime**.

As regards the practical uses of the calcium compounds, the fluoride is used as a flux; calcium silicate enters into the composition of glass; what is known as "luminous paint" is the sulphide of calcium ground up with colourless varnish; bleaching powder is formed by the action of chlorine on any slaked lime; the phosphate is valuable as a manure, and slaked lime is used with sand to form mortar.

Calculating Machines.—The story of the invention and development of calculating machines is largely a story of tragedy,—years of unceasing labour, enormous expense, final disappointment. Pascal, Leibnitz, Baron Napier, Viscount Mahon, Thomas of Colmar, Edmonson, and Charles Babbage are names that stand out prominently in the list of enthusiasts who have tried to simplify or abolish the mental labour involved in addition, multiplication, &c. The tragedy of Charles Babbage and his machine was undoubtedly the most heartrending of them all—twenty years' toil, £6,000 of his own money, and £17,000 of the nation's; and now the unfinished machine is exhibited as a curiosity in the South Kensington Museum!

The coming of the typewriter, coupled with the certainty of the great financial success awaiting any machine simple enough to admit of production at a reasonable price, resulted in the invention of several automatic machines towards the close of the nineteenth century. In England the best known is the "Burroughs Adding Machine." £50,000, and a period of eight or nine years' labour were spent before this machine reached perfection. Its purpose is to register and add up sums of money, and so is of great value in large engineering businesses, railway, government and municipal offices, &c., &c. In appearance and size the adding machine is not unlike a typewriter. The keys are arranged in banks bearing the numbers in regular order from 1 to 9, and as in a typewriter these keys are struck in the desired order when an amount of money has to be registered. When the several columns of pounds, shillings and pence have been registered, a "Total Key" is depressed, a lever is pulled, and the grand total is immediately printed at the foot of the column. Between 2,000 and 3,000 items per hour can be listed with a little practice.

Another calculating machine of particular value in engineering factories automatically subtracts time of day from time of day, *i.e.*, it records the time when a workman commences a job, and automatically subtracts this from the time when he finishes it, thus showing the exact number of hours and minutes taken on any particular piece of work. This is an American invention, and is called the "Calculagraph." A record card bearing the workman's number, the department, order number, date, and name of job or operation is slipped in a slot under a platen in front of the clock dial, and a lever on the right-hand side of the machine is pulled, thus making an impression of and recording on a dial the time (hour and minutes) at which the work is commenced. When work is stopped the same card is re-inserted in the slot, a left-hand lever is operated, and two new dials are stamped, one showing the number of hours, the other odd minutes, which have elapsed since the first insertion of the card. The machine is small in size and can be conveniently sunk in a shelf or desk.

Calibrating.—Signifies testing the accuracy of a machine or instrument which is used for testing purposes itself. As these, like other

mechanisms, are liable to get out of order, due to wear, ill-usage, or accident, it is necessary to have well-recognised methods of ascertaining their amount of departure from accuracy with a view to rectification. The term therefore is nearly co-extensive with mechanical construction, only that usage restricts it to a few articles. We do not speak of calibrating a lathe, or any ordinary machine tool. But we calibrate pyrometers, testing machines, thermometers, and electrical instruments, and the devices adopted will be found under **Pyrometer, Testing Machine**, and other heads.

Caliper.—This term has a far wider scope now than formerly. Besides the plain jointed type, having two legs pivoted upon a pin, more elaborate varieties of the same design have been evolved, partly because of the necessity for finer and more careful measurements, and partly because many firms have taken up the manufacture of these instruments, and have naturally introduced new kinds, as well as improved on the former shop-made article. The Vernier and the Micrometer calipers have also grown into prominence due to the great advantages which they possess for accurate measurements, supplying means of reading off the dimensions of a piece, which the ordinary calipers do not, except by reference to a rule or other standard.

The common forms of caliper for external and internal work respectively are seen in Fig. 95 at A, B, and C, the last made for going deeply into small holes. The legs are of sheet steel, riveted at the joint with washers, to provide for an even motion and lasting wear. The good fitting of the joint is of great importance, since if the faces are finished badly, and allow the legs to work hard and slack at different positions, the calipers will be useless for good work. Screw joints are increasing in favour because they provide a ready means of effecting variations in the frictional contact of the legs. Two sectional views of such joints are shown at D, the first having a plain screw and nut, the second a combined nut and washer passing through the legs, thus forming a pivot, and tightened with the washer forced on the squared end of the pivot piece by the central screw. Sometimes an hexagonal nut is used for the tightening, and occasionally a little handle like that of a bench vice, the idea being in the latter case to jam the leg joints firmly, so that they are locked securely after the setting is effected.

Three other forms of calipers are seen at E, F, and G; the first a compass, or hermaphrodite caliper, used chiefly for marking lines with the point, while the turned-down leg is guided by the edge of the work. Lines and centres are also tested. The example shown has an adjustable point, although the leg is often made solid right down. F is a registering caliper, for measuring a chambered hole, the external legs simultaneously indicating the bore diameter, which is then taken off by other inside calipers, or rule, before the double type is closed in to permit of removal from the hole. G is a combination design, embodying inside calipers, and also dividers; or, by reversing the pivoted legs, outside calipers.

The alterations of caliper legs are effected by tapping them lightly, and although this can be made to give very accurate results, the time consumed is often unnecessarily long. To avoid this trouble, various screw adjustments are fitted, shown in the next figures. H has a short extra leg pivoted and fitted at the end with a nut; a screw having a bearing fastened to one leg passes through the nut, and provides for fine adjustments. At J a somewhat similar fitting is shown with a flat spring resting in a slot, and bearing against a pin inserted in the leg, so keeping the tension against the screw. The caliper also provides for swinging one leg out to clear flanges or chambered recesses, in the case of the internal type K, and returning the leg to position again without affecting the register. This is effected by an auxiliary leaf which binds one leg to the pivot. On releasing the two the leg may be swung out or in to clear, and then returned against a stop to its original position. A different kind of caliper is seen in the five next figures:—the spring pattern, the chief advantage of these being their capacity for ready and delicate adjustments.

The legs are pivoted upon a pin, and the curved spring, fitting by convex ends into grooves in the legs above the pivot axis, causes them to move outwards as the nut on the screw is ran back. The screw passes through a boss, and has one end attached to another boss

swivelling in the leg, so that alteration of angle is automatically provided for; this is shown at L and M. In examples N, O, P the screw passes through the legs themselves (which are made thick enough), being pivoted in one. P is a keyhole caliper used chiefly for measuring the distance from holes or keyways to bosses, &c. The objection to these screw calipers that they cannot be altered so rapidly as the ordinary pivoted ones, has given rise to the development of various quick-acting nuts, which release their hold on the screw if the legs are pinched inwards with the fingers, so that the nut can be slid along instantly. One kind, Q, has a peculiar nut partially threaded inside, leaving gaps as seen. On releasing the pressure of the leg, the nut may be tipped to throw the threads out of engagement with the screw, thus allowing of rapid sliding motion. When the leg is allowed to touch the intermediate washer, the latter

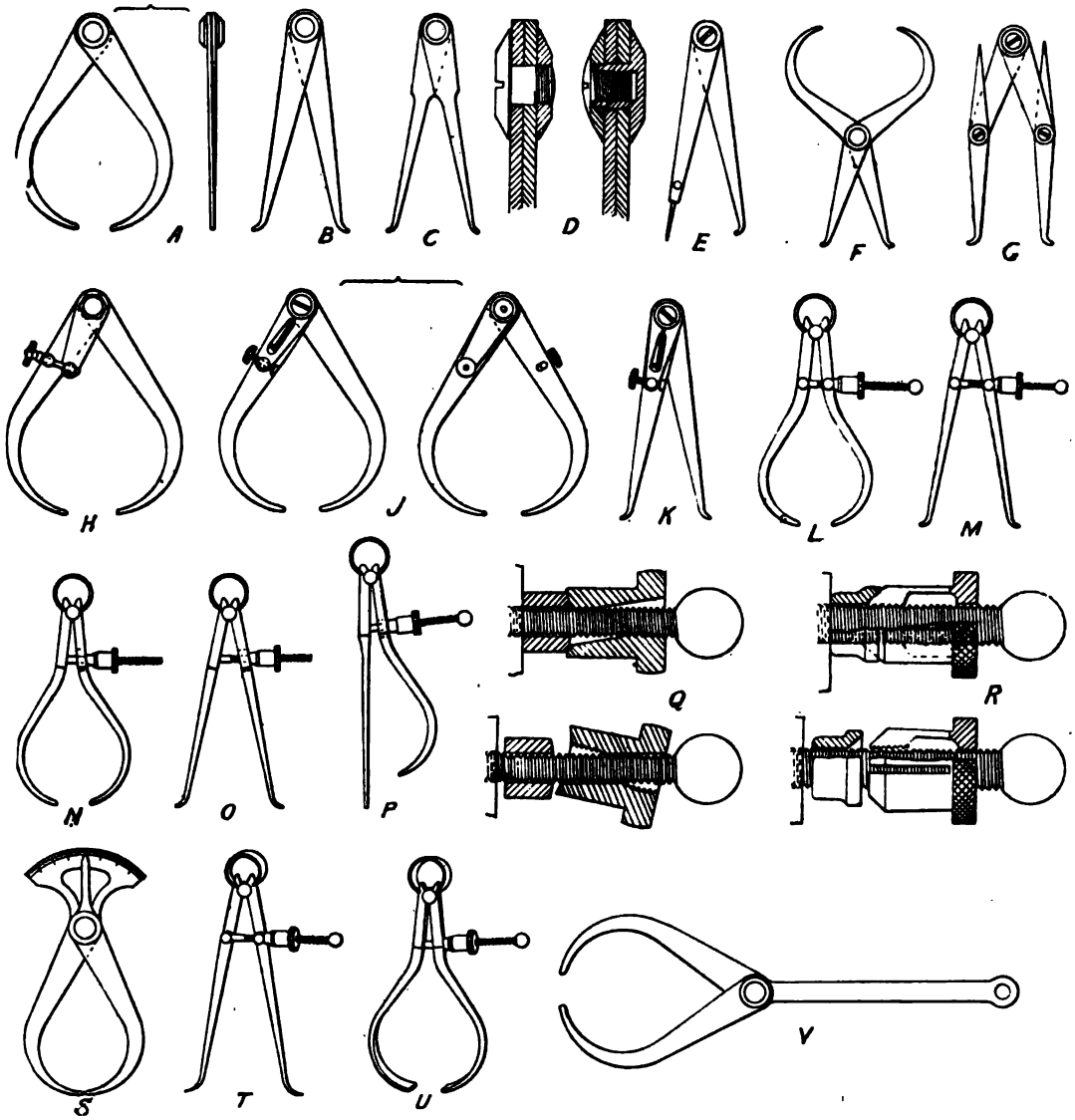


Fig. 95.—Forms of Calipers.

presses against the nut, tilting it into mesh with the screw. Fine adjustment can then be made as usual. R is a design modelled after the spring chuck; the nut is split in four places, and has a short portion of screw inside. As long as the pressure of the legs forces the hollowed washer on to the coned nose of the nut the latter engages on the screw; but when the washer is drawn away, the jaws of the nut spring open sufficiently to permit of sliding, as seen in the lower figure. A covering bush is often provided to keep dust out. It will be noted that a knob is necessary on the end of the screw to prevent the nut from sliding right off.

The incorporation of a measuring device with the ordinary caliper results in some time saving on certain work where it is desired to know the approximate size without reference to a rule. S shows a typical design in which one leg is prolonged to pass over a graduated quadrant on an extension of the other leg. In another a straight rule is pivoted on one leg, sliding in a vee recess in the other, and indicating fine amounts by a vernier.

Special calipers for screw-thread work are seen at T and U, the former for measuring the diameter of internal threads, having fine points for the purpose, the latter for the outside of external threads, the legs being broadened at the ends.

Smith's calipers, V, are of special shape; one leg is prolonged to form a handle, which is necessary because the hand cannot be held close to red-hot work, which may have to be tested during forging.

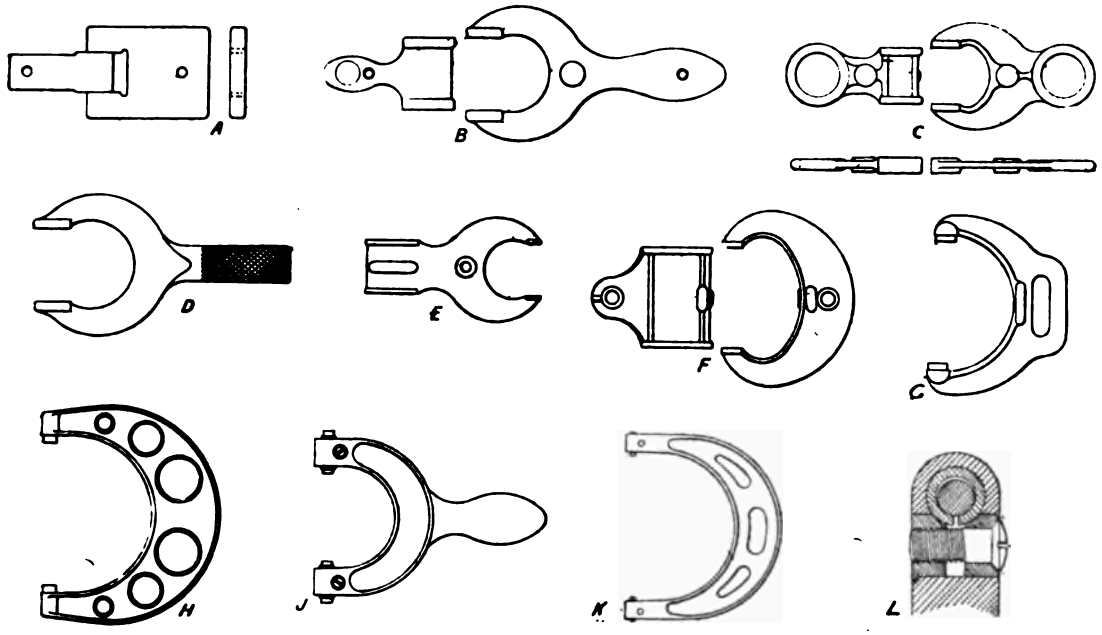


Fig. 96.—Caliper Gauges.

Caliper Gauge.—The limitations of the ordinary caliper are very noticeable on standard or repetition work, for which some form of fixed gauge or caliper is desirable in order to save time and avoid risk of errors. To meet this need the various types of solid gauges, Fig. 96, are designed. These illustrations require little explanation, their variations being due to size, methods of manufacture, and use. Fig. 96, A, is the plainest type, formed of flat

steel; it is also termed a gap or slice gauge. A stronger form and one more suited to larger calipers is the drop-forged type B. The jaws are wider than the body to give a good bearing on the work. C shows ring-handled forms, strongly ribbed. D has a circular knurled handle affording a nice grip for the hand. For convenience, both internal and external jaws are often combined in one body E. The larger gauges are necessarily made shorter as at F, G, H. To further extend the usefulness of caliper gauges they are made adjustable, either with a view to accommodate varying sizes or to effect compensation for wear. J is a plain type having the measuring anvils screwed into the body and clamped by split lugs. K is another pattern with a different method of clamping, held by split bush and tightening blocks, L. A difference between J, K, and the previous solid gauges is that the former have the final adjustments made by turning the screws, while the latter must be finished to size by grinding and lapping. It is possible to close in the jaws by hammering to compensate for wear, and re-lap to size.

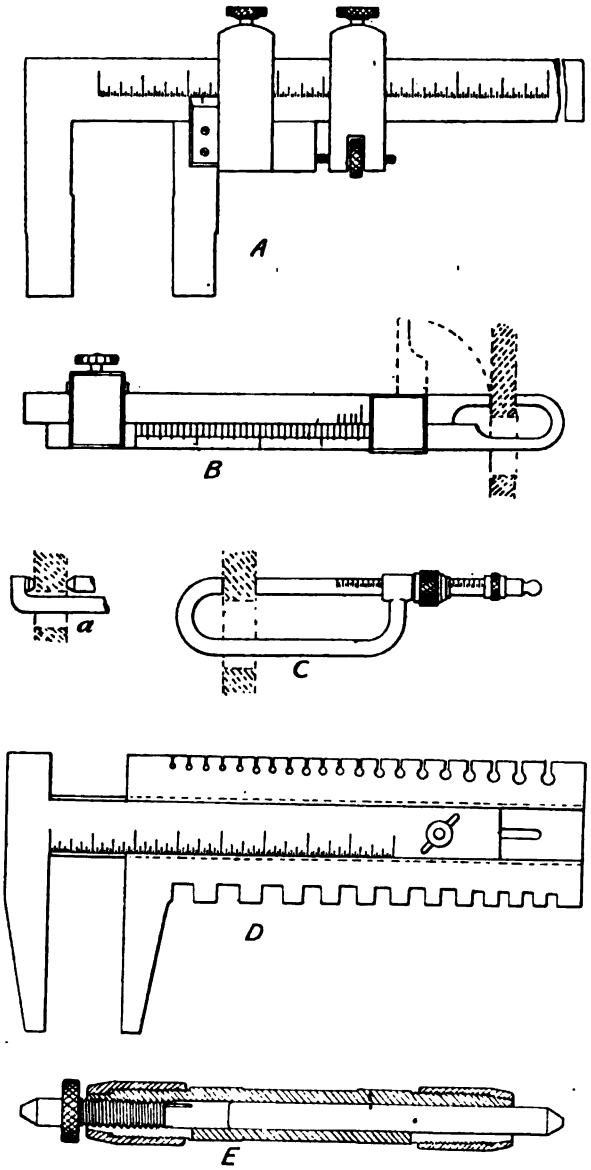


Fig. 97.—Caliper Gauges.

Another class of caliper gauge somewhat resembles the Caliper Rule in form. Fig. 97, A, illustrates a common design (also called a Caliper Square) in which a sliding jaw travels along a graduated beam, being adjusted exactly thereon by a screw worked by a nut held in an auxiliary push block. Many variations are wrought on this pattern in regard to the forms of the jaws. Vernier calipers are also made in this style. The boiler plate gauge B, C is a special type of caliper gauge used for measuring the thickness of plate through a small hole drilled for the purpose. The Chesterman gauge B has a loose swivelling jaw which can be turned upwards (as shown by the dotted lines) to enable the gauge to be tilted up and withdrawn from the hole without affecting the setting. The Starrett gauge C has a friction ring which is slid down against the boss in order to indicate the dimension after the withdrawal of the plunger. At *a* modified jaws are seen for insertion through very small holes. D is a combined caliper and wire gauge. For internal work the adjustable gauge E is employed, being composed of a tube split at one end and provided with a knurled nut for clamping a plain rod, while at the other a short screwed piece is pinched similarly, the screw permitting of end-long adjustment before tightening up. Plain rods of various lengths

are provided so that a good range of diameters may be measured. Gauges of this pattern are also fitted with micrometer screws, for which see the article **Micrometer Caliper.**

Caliper Rule.—The combination of a sliding jaw with a rule forms a very useful tool for rapid measuring of work such as bars, plates, tubes, &c., in storeroom or workshop, the instrument being small enough to carry in the pocket. It is more accurate to use than a plain rule, especially on round work, and also saves the trouble of carrying a pair of calipers in addition to a rule.

Fig. 98, A, shows the Chesterman design (also called a caliper gauge) in 4-inch size, the upper set of graduations being metric. The sliding jaw is clamped by the small screw, the jaw being steadied on the rule by the extension piece underneath. B is a type which has a long jaw sliding in a vee groove in the blade and clamped in the latter by a bolt having its head cut to press on the bevelled edge of the slide, as seen in the detail below B, showing the reverse side of the tool. Graduations on the face of the slide indicate the amount of jaw opening; the back of the blade is also divided as seen in the complete view, the rule being 3 inches long when closed. Another design of this class has the clamping performed by a knurled nut and a screw let into a slot in the blade, the turning of the nut jamming the slide by its edge. It is not considered necessary to clamp the slide in every case; C is a style where the sliding piece straddles over the blade on both sides, having in addition on one side, as seen in the figure, a concave groove in which the thin piece fits and grips by its flexibility sufficiently to hold. The serrations on the bottom edge assist the thumb to push the slide along to span the work. Both wood and ivory rules for draughtsmen's use are also made with a sliding caliper jaw for the purpose of gauging rapidly.

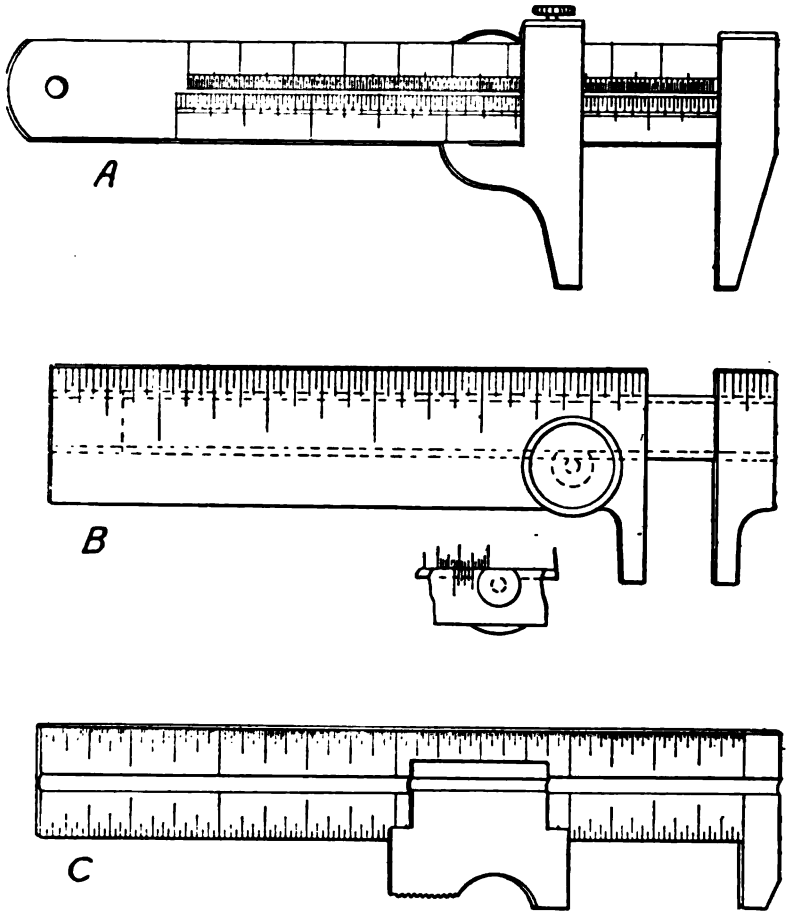


Fig. 98.—Caliper Rules.

Calipering.—The essentials for accurate calipering are delicacy, and fine touch, since the contact of surfaces alone is the means of gauging. There is often a difference between the size obtained by two men from the same piece of work, due solely to variations of the perception of "feel." One may let his calipers bear slightly harder over the faces than the other; in fact

the same man may take two slightly different caliperings successively on the same piece of work. The amount of this variation is of course very small, but it is capable of detection if the micrometer caliper is brought into use for testing the results obtained. For the ordinary run of work, not requiring the highest degree of precision, the common caliper, however, is a good tool in capable hands. Differences in fit for "running" or "driving" can be obtained in work by the use of the internal and external calipers, trying them on each other, and giving due allowance for the clearance or otherwise required between the surfaces of the pieces. Forcing must be carefully avoided, because if the calipers are pushed over the work with any more than the slightest degree of pressure, the legs will "give," and then spring back a little on removal, so registering falsely. Weak calipers are liable to cause more trouble in this respect than those with stiffer legs. Difficulty of another kind is found with the larger calipers, that of the weight of legs causing a slight drop or sag, to minimise which they should be held vertically, in the case of external calipers, and horizontally in internals. A source of inaccuracy also arises from getting the points askew on the work, which is specially noticeable in calipering holes. Wide points tend to prevent this source of error, but at the same time they are not to be recommended for the finest work.

Caloric Engine. *See* **Hot-air Engine.**

Calorie, or **Cal.**—The metric unit of heat. *See* **Calorific.**

Calorific.—Calorific or heat producing is the power possessed by fuels and other combustible substances of producing heat when they enter into combination with oxygen. Heat is measured in units. The metric unit of heat is the quantity of heat which will raise the temperature of 1 kilogram of pure water through 1° Cent. at or near 4° Cent. It is called the calorie. The British thermal unit is the amount of heat necessary to raise the temperature of 1 lb. of water through 1° Fahr. at or near 39°·1 Fahr. It is written B.Th.U. Some authorities say at or near 32° Fahr. Rankine says at 39°·1 F. = 4° C. nearly. Temperature is that property of heat by which it becomes known to the sense of touch. A substance heated to a low temperature is cold to the touch. At a high temperature a body becomes hot. The measure of temperature is the degree, of which there are one hundred on the Centigrade scale and one hundred and eighty on the Fahrenheit scale, between the freezing and boiling points of water, under the normal atmospheric pressure of 760 mm. of mercury, or 14·7 lb. per square inch. Thus the Centigrade degree is nine-fifths of the Fahrenheit degree, and the kilogram being 2·204 lb., the metric heat unit is 2·204 × 1·8 = 3·9672 B.Th.U., or very nearly 4 B.Th.U.

Specific heat is that property of a body by virtue of which it shows a change of temperature for a given absorption of heat. Thus iron has a specific heat of about 0·11, because the same quantity of heat which will raise a pound of water one degree will raise a pound of iron about nine degrees. Heat can only pass from one substance to another when the temperature of the receiving body is less than the temperature of the giving body. By this property a pound of iron which contains so very much less heat than a pound of water, even if much hotter than the water, can nevertheless impart heat to the water, by virtue of such heat flowing into the water at a lower temperature.

Latent Heat.—Latent heat may be described as the specific heat of the state of a body, or that heat which can be put into a body without changing its temperature. Thus, ice at 32° F. = 0° C. may be placed in a pan over a gas flame and a thermometer in the pan will not show any variation. The reading will remain the same until the ice has all melted. If thereafter the heat is continued the thermometer will rise gradually to 212° F. = 100° C. and will remain at that until all the water has boiled away. The latent heat of water is thus 142·6 B.Th.U. per lb. or 79·2 cals. per kilo., and that of steam at 212° is 965·7 B.Th.U. or 536·5 cals. per kilo., these amounts of heat being absorbed by ice and by water during the process of conversion to water and to steam respectively, without change in the temperature.

Temperature is usually measured by the expansion of mercury in a small glass tube. High temperatures are measured by the expansion of solid bars of metal, and still higher temperatures by electrical effects. The quantity of heat

generated by the combustion of a fuel is measured by the rise in temperature of a mass of water produced by burning a small quantity of the fuel in a chamber surrounded by the water. *See* **Calorimeter**. By this instrument it is found that carbon in the amorphous state will generate 14,647 B.Th.U. per lb. = 8,137 cals. per kilo. Hydrogen will generate 62,100 B.Th.U. or 34,500 cals. per kilo.

The temperature of combustion varies according to conditions. It depends upon the weight of substances active or inert which are present, and upon the specific heat of these substances, or of the products of combustion.

Thus, when burned with pure oxygen, carbon yields carbon dioxide or CO_2 to the extent of $3\frac{2}{3}$ lb. per lb. of carbon, and the specific heat of this gas is 0·217. The 14,647 B.Th.U. produced by the combustion must therefore be distributed among $3\frac{2}{3}$ lb. of gaseous products, and the rise in temperature will not be 14,647°, but $14{,}647 \div 3\frac{2}{3} \div 0{\cdot}217 = 18{,}410°$ Fahr. If, however, air be employed instead of oxygen, the weight of the final products will be increased by the amount of the nitrogen of the air, which will be nearly 9 lb., and the specific heat of nitrogen is 0·244, so that the final temperature will now be

$$\frac{14647}{(3\frac{2}{3} \times 0{\cdot}217) + (8{\cdot}86 \times 0{\cdot}244)} = 4988° \text{ Fahr.}$$

When an excess of air is employed beyond the chemical minimum there will be a third term in the denominator consisting of the weight, W, of the excess of air multiplied by the specific heat of air which is 0·237.

Since hydrogen demands eight times its own weight of oxygen, and the specific heat of steam is over double that of carbon dioxide, the temperature of burning hydrogen is not so high as its calorific capacity might at a first glance appear to warrant. Hydrogen temperatures are less than carbon temperatures. With some of the poor gases, as blast furnace gas, there is already so much inert nitrogen present and so much water vapour, that the further combustion of the gas with air produces only a low temperature. In order to get higher heating effects the air to mix with such gas may be heated in a regenerator (*see* **Chequer Work**) as also may be the gas. If heated by otherwise waste heat the final temperature of combustion will be raised by the amount through which the initial temperature is raised by the regenerator. The very high temperatures of combustion in oxygen are not actually obtained, because combustion ceases, and fuels combine no further above a certain temperature. They dissociate and only continue to unite when the generated heat is dissipated. Combustion may thus be prolonged.

Except in refractory non-heat-absorbent furnaces the ordinary temperatures of fuel burned with even an excess of air are apparently not secured throughout the furnace. This is because heat is rapidly lost by radiation, as to the surrounding boiler surfaces. Otherwise the same temperature is secured, whether a fuel be quickly or slowly burned, if an equal quantity of air is employed for each pound of fuel. Great confusion of thought is apt to arise between temperature and quantity of heat. Thus a fiercely urged fire will burn out a certain water tube of a boiler against which the gases from the fire are urged. The same tube will not burn out if the fire burns slowly even with the same air ratio. But in each case the temperature is the same, though it appears less, simply because more heat being produced in the first instance, a less proportion of it is lost by radiation, and there is more heat bombarding the tube, which cannot carry it off at the same rate that its surface receives it. With the reduced rate of burning, the gases do not even make contact with the tube at the maximum temperature, for the tube remains colder and is capable of chilling off the half weight of gas without injury to itself.

Water-cooled boiler surfaces absorb heat rapidly from hot gases. Thus a common average rate is 4,000 to 6,000 B.Th.U. per square foot per hour. But the parts of a boiler next the fire are probably six or eight times as efficient as this average for the whole boiler, the efficiency varying with the square of the difference or head of temperature, and becoming very small below a difference of 200° Fahr.

The calorific capacity of a fuel is calculated from its constituent combustibles as follows:—

$$\text{Cal. cap.} = \frac{14147\,C + 62100\,H + 2500\,S - \left(62100\frac{O}{8}\right)}{100}$$

where C is the percentage of carbon in the fuel, H the percentage of hydrogen, and S that of sulphur; the minus quantity representing the oxygen loss, for any oxygen is supposed already united to its proportion of one-eighth its own weight of hydrogen. The calculated results do not always agree with those given by the calorimeter. This is because the condition of the combined hydrogen and carbon compounds is not known. Some of them absorb, others reject heat when first formed, and these endothermic and exothermic reactions influence the final calorific effects of combustion. Mahler deduced the following formula as representing the average of forty-four tested fuels in metric measures:—

$$x = \frac{8140\ C + 34500\ H - 3000\ (O + N)}{100}.$$

In B.Th.U. this formula is simplified to

$$x = 200{\cdot}5\ C + 675\ H - 5400.$$

The following table gives a few of the more important figures in calorimetry:—

CARBON.

Specific heat	0·1468 to 0·2850	
Heat of combustion per kilo. to CO_2	8,137 cals.	= 32,285 B.Th.U.
„ „ per lb. „	14,647 B.Th.U.	= 3,691 cals.
„ „ „ to CO	4,415 B.Th.U.	= 1,112 cals.
„ „ per kilo. „	2,453 cals.	= 9,733 B.Th.U.
Weight (ideal) of cubic meter vapour	1·072 kilo.	= 0·06696 lb. per cubic foot.
Temperature of vaporisation	3,600° C.	= 6,572° F.
„ combustion to CO in air	1,485° C.	= 2,705° F.
„ „ in oxygen	4,292° C.	= 7,757° F.
„ „ to CO_2 in air	2,753° C.	= 4,988° F.
„ „ „ in oxygen	10,226° C.	= 18,440° F.
Air to burn 1 unit to CO	5·797	
„ „ CO_2	11·594	
Oxygen to burn 1 unit to CO	1·334	
„ „ CO_2	2·667	
Temperature of combustion of CO to CO_2 in air	1,923° C.	= 3,494° F.
„ „ „ in oxygen	7,144° C.	= 12,892° F.

HYDROGEN.

Specific heat, constant volume	2·4146	
„ „ pressure	3·410	
Weight per litre	0·08961 grm.	
„ cubic foot	0·00559 lb.	
Cubic feet per pound	178·83	= 5,063·4 litres.
Litres per kilogram	11,160	= 394·15 cubic feet.
Heat of combustion per kilo.	34,500 cals.	= 136,900 B.Th.U.
„ „ lb.	62,100 B.Th.U.	= 15,560 cals.
„ „ cubic foot	347 B.Th.U.	= 87·45 cals.
„ „ litre	3·091 cals.	= 12·264 B.Th.U.
Specific gravity when liquid	0·0714	
Boiling point	33° absol. C.	= 60° absol. F.
Freezing point	16·7° „	= 30° „
Temperature of combustion, air	2,513° C.	= 4,554° F.
„ „ oxygen	6,762° C.	= 12,202° F.
Air to burn 1 unit weight	34·785	
„ „ volume	2·39	
Oxygen to burn 1 unit volume	0·50	
„ „ weight	8·00	
Heat of combustion (result in vapour)		
„ per kilo.	29,150 cals.	= 115,434 B.Th.U.
„ per lb.	52,290 B.Th.U.	= 13,177 cals.

Calorimeter.—A calorimeter is an instrument for determining the amount of heat in a body, and its essential principle lies in the absorption of the heat of the hot, or heat producing body by a mass of water, the rise in temperature of which is the measure, subject to corrections, of the heat added in the instrument.

The utility of the instrument to the engineer is in the determination of the heat generated by the combustion of fuel. Essentially the fuel is burned in a chamber in the middle of the instrument, and the products of combustion are cooled to the temperature of the instrument and the water inside it, which of course is warmed by the fuel. From the known weight of the water and of the instrument itself, and the rise of temperature and the specific heat of the instrument, the added heat is calculated. Corrections are necessary on account of loss of heat by radiation during the period of experiment.

The Thomson Calorimeter, for approximate determinations, consists of an oxygen holder connected by a tube with a cock to a bell glass containing a crucible in which the fuel is burned. The crucible is carried in the bell glass by light metal springs on an earthenware base, and the whole is immersed in an outer glass jar, which holds 2 kilos = 4·408 lb. of water, and contains an agitator or stirrer. The fuel is ignited in the crucible, which is promptly plunged into the instrument, and combustion is maintained by a stream of oxygen from the holder. The products of combustion escape round the mouth of the bell jar and bubble up through the water, to which they impart their heat. When combustion is complete the bell jar can be allowed to fill with water by the opening of an escape pipe, and when by aid of the stirrer, the instrument and water have acquired a uniform steady temperature, the calculation can be completed from the reading of the thermometers. Radiation may be provided against or minimised, when by experience the rise of temperature of the instrument is known approximately. The test may be started with the instrument as much colder than the room as it will finish warmer. The instrument will therefore absorb as much heat as it loses, and correction will not be required.

There are many varieties of calorimeter between the above simple form and the highest class of "Bombe" or constant volume apparatus, of which the best is the Berthelot-Mahler. This consists of a steel shell capable of withstanding fifty atmospheres pressure, and of ductile quality, very pure, and enamelled internally. Its capacity is 654 c.c. at 15° Cent. = 40 cubic inches at 59° Fahr. It weighs complete about 4 kilos. = 8·8 lb. Externally the shell is nickel-plated. The cover is a clamped iron stopper fitted with a valve of nickel and an electrode well insulated, and a platinum wire to the interior passes through the stopper. A light plate of platinum is carried by a wire from the stopper. This plate carries the fuel. This Bombe is contained in a vessel of thin brass, holding 2,200 grams of water = 4·85 lb.

Oxygen is admitted to the Bombe under pressure. One gram of fuel is placed on the platinum carrier plate, a small 26 or 30 S.W.G. iron wire is attached across the two platinum wires and the cover is screwed hard on. Oxygen is admitted carefully so as not to disturb the fuel, and the Bombe is placed in the water bath, and when temperature has steadied, the charge is electrically fired, the iron wire burning in the oxygen and firing the fuel. The instrument is of course calibrated for specific heat. The soft steel is rated at 0·1097; the brass at 0·093; mercury, platinum, and lead at 0·03; and a correction for radiation is made as above if necessary.

Liquid fuels are dealt with by the addition of absorptive substances such as pumice-stone or asbestos. Substances difficult to burn are assisted by the addition of a known weight of naphthalin, the calorific capacity of which is known, and can be subtracted from the result. Fuller descriptions of the above instruments and their use may be found in Booth's "Liquid Fuel."

Calorimeters by which the amount of heat in gases is determined are the same in principle. Two of these are shown in Figs. 99 and 100. The first is the Simmance Abady type, suitable for testing producer gas, coal gas, or other kinds.

It is made of stout copper or brass, lagged with mahogany, has a water-level tube for enabling the supply of water to be observed, an adjustable shutter for regulating the rate of passage of the products of combustion, so that their exit at a proper temperature from the instrument is secured. A tilting bucket is provided for the transfer of water from waste to measure

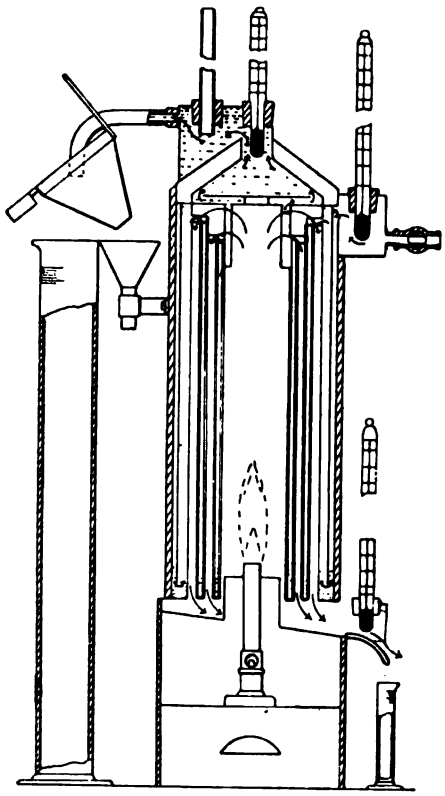


Fig. 99.—Simmance Abady Calorimeter. (Messrs Baird & Tatlock, Glasgow.)

without affecting the flow. The furnace stand is of teak with cast-iron top and spout for condensed product, and a glazed door is fitted to prevent draughts, in order to secure steady combustion. A composite air burner, suitable for all gases is provided with an angled mirror in which the flame may be seen during a test. There are three open-scale thermometers to take the temperature of inlet and of outlet water, and outlet products.

Junker's calorimeter, Fig. 100, is also based on the transmission of heat from a flame to a current of water. Measurements are taken of the quantities of gas burned, and of the quantity of water passed through, together with the differences in temperature of the water on entering and leaving the apparatus. In Fig. 100 a flame is enclosed in an annular vessel of polished copper. The annular space is traversed by a number of small copper tubes which connect the top and bottom of the chamber. The heated gases circulate within the tubes from top to bottom, and a current of water ascends outside the tubes, so producing counter currents of heat and water. The spent gases escape at atmospheric temperature.

To maintain the pressure of the water current constant, two overflows are provided, while its amount is regulated by the plug stop-cock seen at the bottom left-hand corner. Even distribution is ensured by a baffle plate which surrounds the lower ends of the tubes, while in the neck of the apparatus—the narrowed portion above the cone—several discs and cross slots are arranged to ensure an intimate mixture of the heated water before it reaches the thermometer above. Provision is made to collect the water which is formed during the combustion of many gases in the annular space at the bottom, and to pass it through the tube into a measuring glass.

Two thermometers indicate the temperature of the entering and escaping water. The water supply tube A is connected to the nipple, in the centre of the upper container; the other nipple is provided with a waste tube B to carry off the overflow. This overflow must be kept running while the readings are being taken. The nipple of the heated water outlet C, is connected by an indiarubber pipe with a large measuring glass—not shown. A smaller measuring glass—not shown—is provided under the condensed water outlet E to collect any condensed water.

The water supply must be capable of passing from 1 to 3 litres per minute. A calibrated gas meter is necessary to pass $\frac{1}{10}$ cubic foot for one revolution of the large index pointer D in the gas supply tap. The two graduated measuring glasses must have capacities of 2 litres, and 100 cubic centimetres respectively. The thermometers must permit of readings of $\frac{1}{10}°$

Cent. between zero and 50° Cent. If the results are required in British thermal units, the result in calories has to be multiplied by 3·96828, or approximately 4·0.

As the calorimeter has a maximum capacity

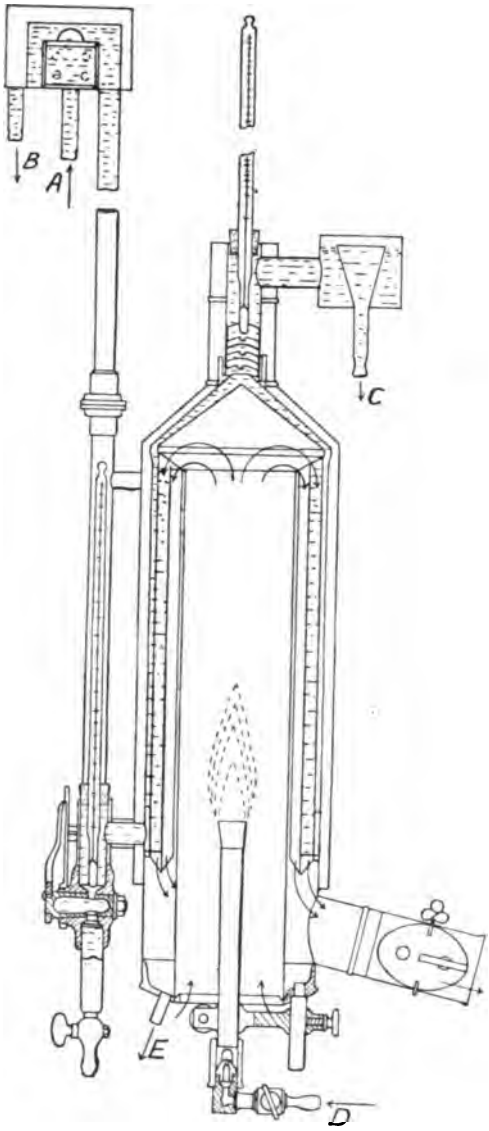


Fig. 100.—Junker Calorimeter. (Messrs Baird & Tatlock, Glasgow.)

for absorbing 2,500 calories per hour, the quantity of gas burned during the tests should be regulated to produce only from 1,000 to 1,500 calories in that time. This means that for burning different gases, the consumption should be as follows per hour:—Illuminating gas from 4 to 8 cubic feet. Hydrogen, 8 to 16 cubic feet. Dowson gas, 16 to 32 cubic feet.

As a calorie is the quantity of heat required to raise the temperature of water through 1 degree Cent. the following equation gives the heating value of a gas:—

$$H = \frac{WT}{G}$$

where—

H = the calorific value of 1 cubic foot of gas.

W = the quantity of water heated in litres.

T = the difference in temperature in degrees Cent. of the inflowing and outflowing water.

G = the quantity of gas in cubic feet burned during the experiment. This gives the gross value, including latent heat. The nett calorific value is in many cases 10 per cent. less. For every cubic centimetre of condensed water collected in the small measuring glass, an allowance of 0·6 calorie must be made.

Cam.—A cam is a device for producing any required motion that cannot be so well obtained or not at all by combinations of links and toothed gears. An objection to link motion is the wear on the pins, which when it occurs dislocates the motions so much as to mar their accuracy.

Cams will run at high speeds, and retain their accuracy for a very long period. They often develop much friction, but this is lessened by the use of rollers in some cases, by hardened surfaces, and lubrication. And generally it is not the cam that wears, but the roller and its stud, which are easily renewed.

The elementary principle of the cam can be best observed in the common heart shape with equal lobes, which is able to impart a uniformly reciprocating movement to a bar. But this is a very simple form, for many cams must embody periods of rest as well as rotation, and periods of accelerated or retarded movement. Moreover it is not always convenient to have a rod, pin, or roller bearing against the outside edge of a cam, but face control is preferable. These facts explain why the forms of cams in use may be numbered by hundreds, since it is practicable to design a cam for nearly any movement

required. Various details of cams and camwork will be found in these volumes.

Camber, Cambering.—Denotes the curving or arching of a beam. It is often imparted designedly as in the upward curving of the tie beam of a roof truss in order that the effect of the load shall tend to straighten the beam instead of bending it downwards. Thus the king, or queen posts are cut 1 inch or 1¼ inch shorter than their proper length for every 20 feet of span, to which amount the beams are cambered or curved upwards.

In the work of the foundry and pattern shop cambering relates to the amount of curvature imparted to patterns to counteract the curvature which certain forms of castings assume in cooling. Patterns for such, if made straight, would produce curved castings, unless, and which is sometimes done, the moulder imparts a curve to the pattern by loading it at the time of ramming. *See* **Castings—Curving of**; and **Dished Ends.**

Camber also signifies the amount of rise (versed sine) in a curved leaf spring.

Camera.—Very few branches of photography make such severe demands upon the camera in respect of variety of movements as engineering photography. The most suitable instrument for this purpose should be fairly heavy and perfectly rigid, the ordinary type of "tourist" camera being too light and flimsy for continual use in the open, in yards, or elevated positions. The bellows should allow of long extension in order that lenses of long focus, a single component of a rectilinear or anastigmatic lens, for example, may be used. This is often required when a large photograph of some detail is necessary, such as the holders of turning tools in a turret lathe—an object cannot be photographed full size unless the camera can be extended to double the focal length of the ordinary lens. Another consideration is that such long extension and the use of a lens of long focus give a better perspective in a picture. Fig. 61 on Plate III. in Volume I. is an example of slightly exaggerated perspective, a defect which is less noticeable in the pipes and track on Plate VIII. The effect of such exaggeration is of course to make an object appear much more massive and much longer than it really is. A long extension of bellows requires however a very rigid front.

On the other hand, it is often necessary to

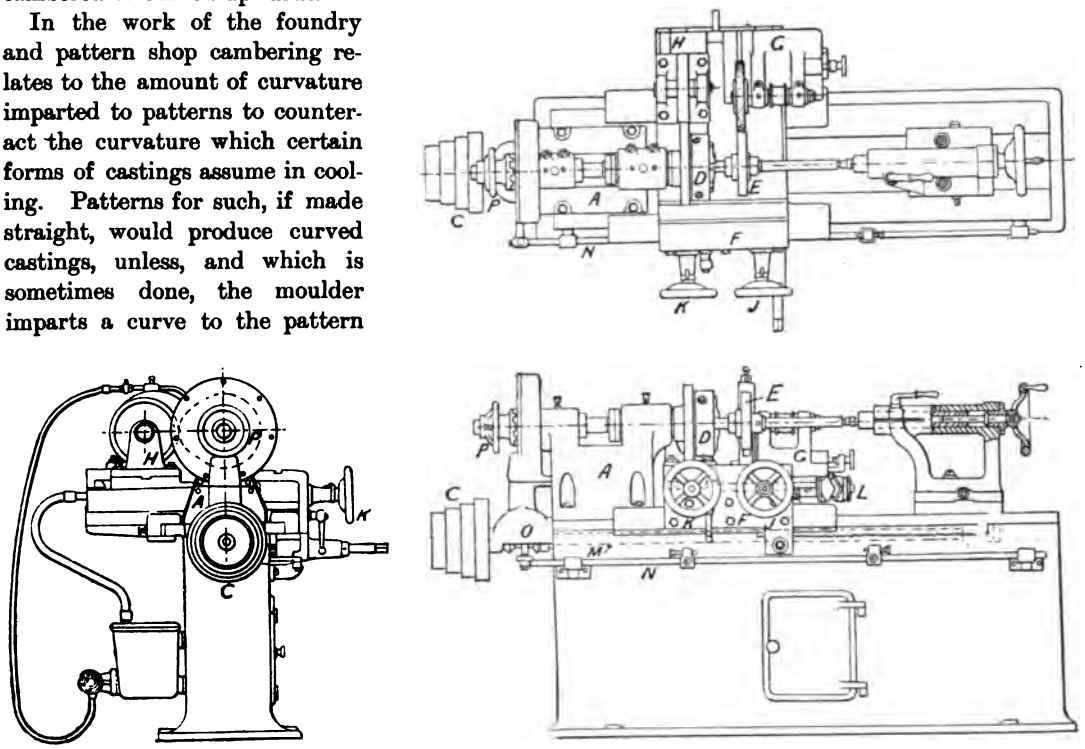


Fig. 101.—Cam Grinding Machine.

push back the bellows so that the lens is but a few inches from the focussing screen. This admits of what is called wide angle work, and is necessary in such interiors as those on Plates XI. and XII. or outdoors in the photography of such structures as a Temperley Transporter, a bridge, or in any case where the object embraces a wide angle as compared with the position of the camera. Square bellows are therefore preferable to the conical shape, because the latter are forced back against the plate and a portion of the picture is frequently cut off. It is also an advantage to have a provision for racking the back forward towards the lens for wide angle work. A very good range of extension for a whole plate ($8\frac{1}{2}$ by $6\frac{1}{2}$ inches) camera is about 27 inches longest extension, and 3 inches shortest extension.

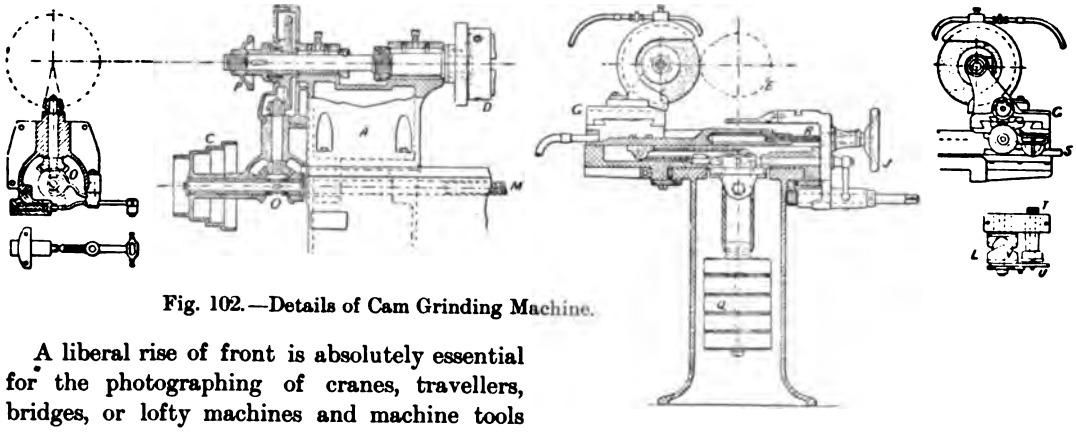


Fig. 102.—Details of Cam Grinding Machine.

A liberal rise of front is absolutely essential for the photographing of cranes, travellers, bridges, or lofty machines and machine tools such as for instance a big vertical lathe. A movement which goes to the other extreme is needed when a photograph is to be taken from above, of a masonry dam or any work or machine viewed from an elevated position. An excellent example of a photograph requiring this movement is seen in the picture of the carrier wire ropeway and lighthouse in Plate I. A dropping baseboard is the best means of accomplishing this. Another desirable action in the camera should be a means of swinging the front or lens panel so that the lens may be tilted upwards in photographing an overhead crab or any lofty structure. This is better than swinging the back of the camera. A spirit level or plumb indicator is also a useful addition to the apparatus to ensure that vertical lines in the object shall be vertical in the photograph.

See also **Anastigmatic Lens** and **Photography—Workshop.**

Cam Grinding.—The greatly extended employment of cams, due to the immense number of gas and oil engines in use, has resulted in attention being turned to their economical and accurate production by milling and grinding. The latter process has the obvious advantage that the finishing can be effected after hardening, while milling must precede this operation.

An example of a special machine for cam grinding by Mayer & Schmidt is here illustrated. Figs. 101 show plan, front elevation, and (back) end elevation, which may be compared with the enlarged details, Figs. 102, the same reference letters being used in each. The machine resembles a cylindrical grinder in the possession of head, tailstock, and grinding-rest, but has several modifications. The head A carries a spindle B driven from the four-stepped pulley C through the two sets of bevel gears seen. The jaw-chuck D grips the stems of cams, or else a mandrel (as shown) on which the cam is mounted, the back centre being brought up for support. The cam is seen at E, and the shape imparted to it by the grinding wheel on the carriage G is controlled by the master-cam seen directly behind the chuck. A cross-slide H carries a roller, pressed against the master-cam by the weight Q, pulling a rope attached to the underside of the slide, as noticed in the section. When the machine is started, therefore, the

spindle B being rotated, as well as the grinding wheel, the latter travels back and forth, finishing the cam to outline. The handwheel J is for feeding the wheel up to grind, and K for bringing the tracer roller into contact with the master-cam before starting. The screws fit in telescopic nuts, as seen in the cross-section, the nuts permitting of the reciprocating motion taking place, which could not occur were the screws passed through ordinary fixed nuts.

At L is seen the mechanism for traversing the wheel to and fro across the cam periphery, to secure even grinding. The cross-slide motion causes a rack S (see detail) to rotate a pinion T, which in turn by means of a slotted disc on U, and ratchet-pawl, turns the cam-piece V. The face, and groove type, because a greater depth of cut can be conveniently taken than when turning. The "form" device is applied (as in turning and grinding), the pressure of a roller against the copy controlling the movements of the milling-cutter, or of the work. Cam grooves may be easily produced of uniform width, because the cutter ensures parallelism.

Camming.—On reference to Vol. I. in the article on **Automatic Screw Machines** it is seen that the automatic movements of the work and the tools are effected by cams attached to the peripheries of drums or to the faces of discs. Through the courtesy of Messrs Alfred Herbert, Ltd., we are enabled to give drawings showing the lay-out of the cams, for the type of machine

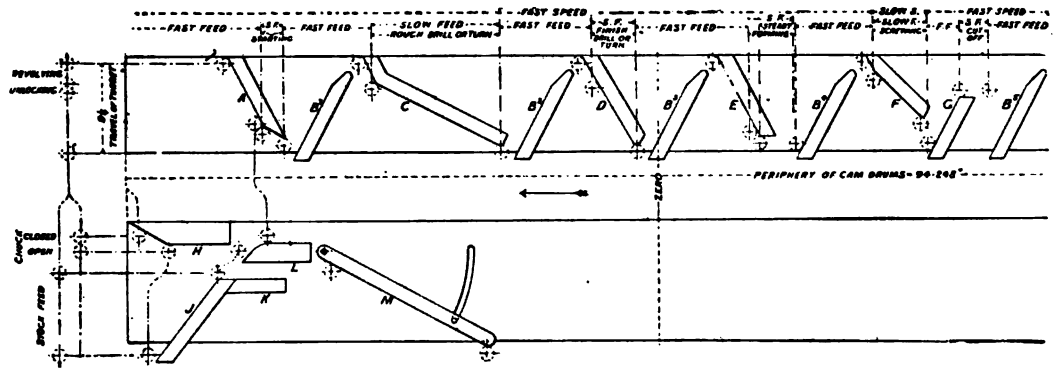


Fig. 103.—Development of Drums for Turret and Chucking Mechanism.

latter controls a pin attached to the wheel slide, and moves the slide to and fro.

The machine can also be used as an ordinary grinder, in which case the crown bevel at the headstock is put out of gear with the spindle B, by disconnecting the clutch, moved out by the handwheel P and screw. A belt is then put on the chuck D to impart a high speed of revolution. The main carriage is then travelled along the bed by the screw M, driven from C through the bevel gears in the box O. A clasp nut, seen in the sectional view, is engaged with the screw by the short lever under the handwheels. Reversal of the carriage movement takes place by striking the dogs on the rod N, the latter throwing the sliding clutch inside O to right or left, and reversing the screw. Cams up to 300 mm. diameter can be ground on this machine.

Cam Milling.—Milling is a very expeditious method of finishing cams, both of edge, seen in Figs. 163, 164, 165, 166, Vol. I. These cams are of standard pattern, and serve for all sizes and classes of ordinary work (constituting the majority done). The upper Fig. 103, shows the turret drum, and the lower that for the stock feed, and gripping; for the purpose of laying out, the drums are developed as flat strips.

Fig. 103 is almost self-explanatory, the printing indicating the functions of each cam, and the relative speed thrown in at the time. The terms "fast *speed*" and "slow *speed*" refer to the rate of the spindle revolution—the "slow speed" being employed when screwing. "Fast *feed*" and "slow *feed*" relate to the rotation of the drum shaft, as explained in Vol. I., p. 234, second column. It will be noticed that the strips C and F are laid at an angle more nearly parallel with the sides of the drum, thus giving a slower movement to the turret pin than when set more obliquely as in the case of all the other

strips; C and F are for heavy rough-drilling or turning, and screwing respectively. In the upper Fig. 103, it will be seen that each feeding cam for the turret, marked A, C, D, E, F, has a companion cam indicated by B^1 to B^5, every one of these B's serving to return the turret rapidly ready for the next cut, the drum being revolved at the high speed while a returning cam is in operation. Two sets of these feeding and return cams are seen marked in Fig. 163, Vol. I. In Fig. 103 it will be observed that there is a place marked "steady, forming," and one "cut-off," where the cams have no effect upon the pin; this is because the turret has to remain stationary, holding a steady plug or a bush at the end of the work which is "formed" by the cross slide, and while the cutting off is proceeding. A zero line is marked upon the drum as seen, from which all measurements are taken in attaching the cam strips. Fig. 104 gives the various cam strips, showing their bolt holes, angles, and bevelled edges. The latter are desirable because the pins of the turret and headstock have to clear the drums slightly. The cams are made of spring steel, tempered, except H and K, which are of double shear steel. The adjustable cam M is made thin, and has facings to fit around the drum.

The disc and cams for the cross slide are seen in Fig. 105. Cam A operates the cut-off lever at the back of the machine, C actuates the forming lever at the front. B is for returning the cross slide to the centre, acting on the front lever, and the inner portion of cam A performs the same function on the back lever.

Cam Turning.—This is done by the use of a master cam mounted conveniently on the same mandrel as the cam to be turned. The slide rest has its screw removed and a weight is hung to the rear; a finger or tracer-roller is attached to the rest to make contact with the master cam. As the latter revolves it therefore causes the rest to reciprocate and move the tool accordingly, so that the work is turned to the same profile. An exactly similar application will be seen in the **Cam Grinding Machine**, p. 128, where a wheel occupies the place of the tool in the case of turning in the lathe.

Canal Lift.—A fine piece of engineering work due to Mr Edwin Clark of the firm of

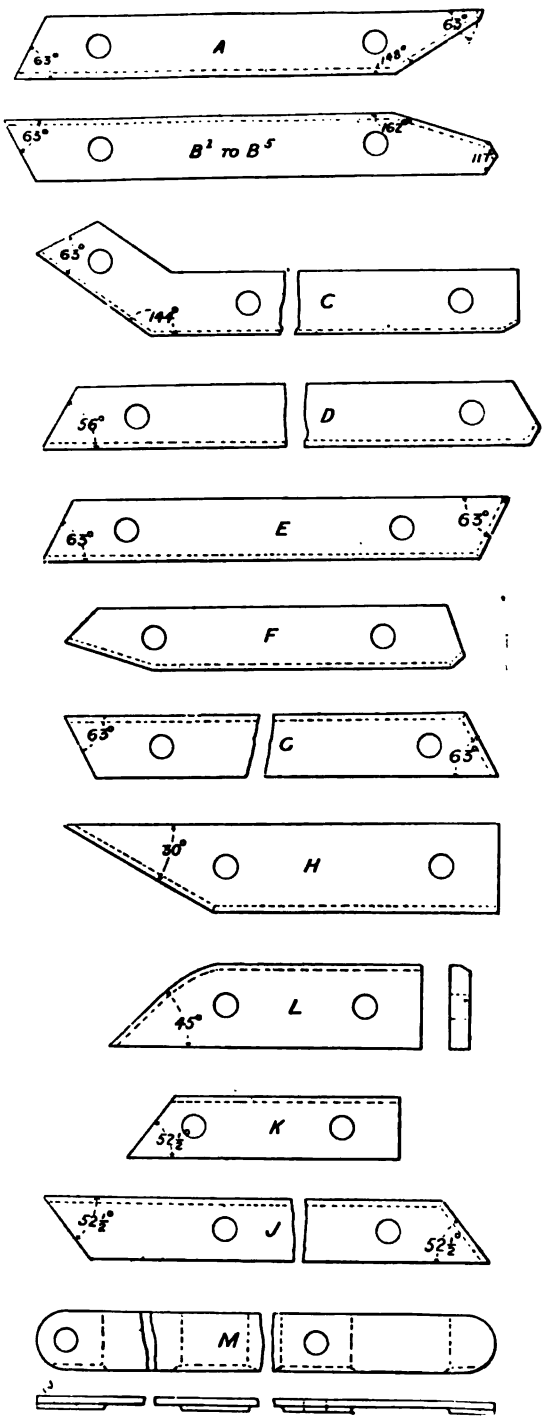


Fig. 104.—Cams for Turret and Chucking Drums.

Clark, Standfield, & Clark. The first of this kind was constructed to effect a junction between the River Weaver and the Trent and Mersey Canal, and is known as the Anderton lift. Others have been erected at Les Fontinettes on the Neufossé Canal near St Omer, France, and on the Canal du Centre at La Louviere near Mons, Belgium. The latter joins the Mons and Condé Canal and a branch of the Charleroi and Brussels Canal. The great difficulty here, which led to the selection of the lift in preference to locks, was the difference in height of the two canals, 89·45 metres (293 ft. 6 in.) in a distance of 15 kilos (9⅓ miles). The water supply was insufficient to provide the 40,000 tons per day that would have been required by locks, the whole of which would have had to be replaced. Hence the installation of hydraulic lifts, of which four have now been erected. See Fig. 106, Plate VII.

The system is in brief this:—Upper and lower reaches of canals are connected by means of a hydraulic lifting trough or pontoon, having a rise and fall of 15·397 metres (= 50 ft. 6¼ in.). This trough is made of the same dimensions as the lock employed on some sections of the canal to take the broad gauge barges. It is 141 ft. long, 19 ft. broad, and the mean depth of water in it is 7 ft. 10½ in. It is built up of girders and plating, and is opened and closed at each end by doors, which are raised and lowered. The end of the upper canal is carried out by means of an aqueduct 58 ft. 5 in. long, constructed similarly to the troughs, and terminated also with a movable gate. The lower canal also has a termination of metal provided with a similar gate. So that an upper canal projects out with a gate; the movable length of canal has two gates, and the lower canal has a gate. If the movable trough is lifted into line with the aqueduct of the upper canal, and the adjacent gates in each are opened, it forms a continuation of the canal for the time being, and a barge can enter it. Now if the gates are closed, the trough with its barge is self contained. Then, when lowered, and its end brought next the termination of the lower canal, and the gates opened, the barge will be able to leave the trough and pass into the lower canal. Similarly the operation can be reversed.

The joints at the ends of the canals and troughs are made watertight by bevelling the ends so that they wedge against one another.

In order to avoid having to pump lost water up to the top, the troughs are duplicated, so that one comes down while the other is going up, and the canals are divided into corresponding branches. They therefore nearly balance each other—not quite, because of friction, and of the displacement of the emerging ram on which the rising lift is carried. No machinery is required to lift the rising trough. This is a general statement, but some of the principal details call for notice.

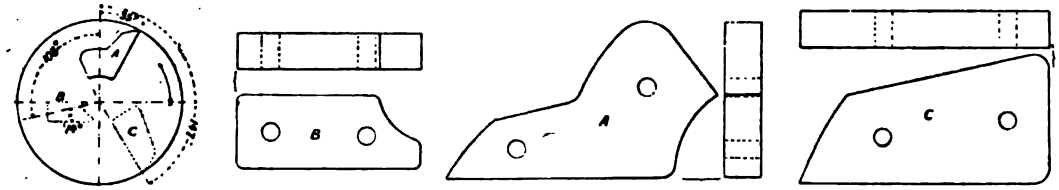


Fig. 105.—Disc for Cross Slide, with its Cams.

The weight of each trough with its contained water is about 1,100 tons, and the time taken in traversing the distance of 50 feet is 2½ minutes. The friction of the rams, and the difference in a ram immersed and one coming out of the water requires about 60 tons more water in the ascending trough than in the descending one. It amounts to about 10 inches more depth of water, which is simply let in from the upper canal, stopping the trough short of its full height to receive it. The only machinery therefore required is to compensate for leakage, or to raise a trough that may have gone too low, and to lift the doors. Two turbines are provided for this, capable of furnishing 5,000 gallons per hour.

An interesting detail of the construction is the presses. The enormous load of the trough is supported on a single ram 6 ft. 6¾ in. in

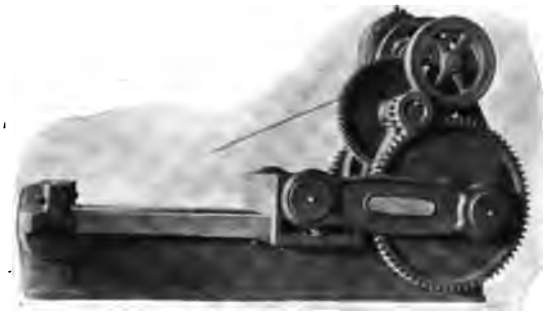


Fig. 86.—Bulldozer. (Williams, White, & Co.)



Fig. 87.—Dies Operated by Bulldozer.

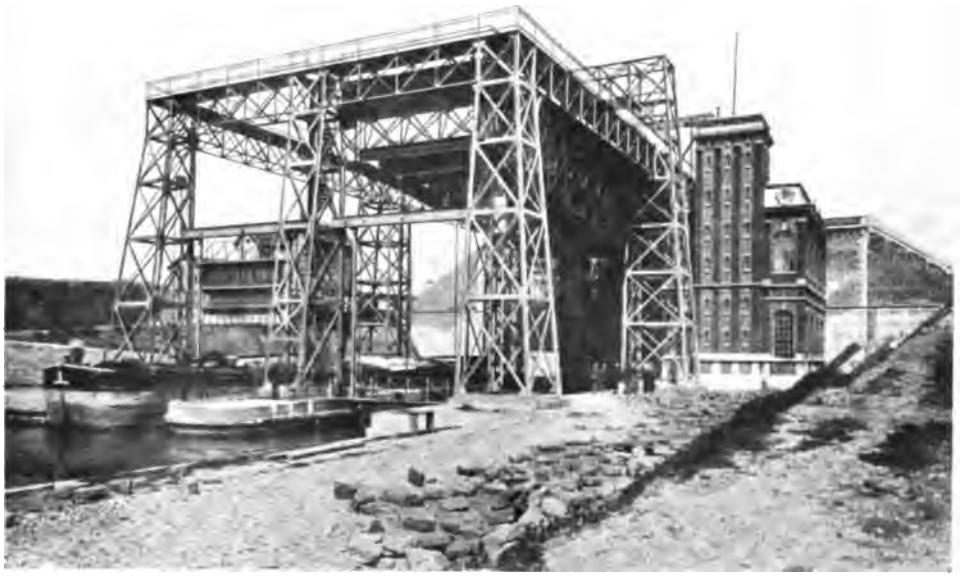


Fig. 106.—Canal Lift.

To face page 132.

diameter, and the corners of the trough are guided against wind pressure. As the working pressure on the press is 470 lb. to the square inch, cast iron alone would not have been reliable. The central portion, therefore, is of cast iron, and weldless steel coils 2 inches thick are shrunk on. The ram and press cylinders are in lengths of about 7 feet, and bolted together. But the internal flanges used in the ram lengths could not be adopted in the press, so the end coils were flanged to receive bolts.

In another of these lifts at Les Fontinettes on the Neufossé Canal, near St Omer, France, the troughs are 129 ft. 7 in. long, by 18 ft. 4½ in. wide, and carry a depth of 6 ft. 6¾ in. of water, and the lift is 43 ft. The installation resembles the one just described, but is not quite so powerful.

Canals.—Canals are constructed for (*a*) drainage, as in the Fens, (*b*) irrigation, as in Egypt and India, and (*c*) navigation; and canals for navigation may be either inland canals for barges, or ship canals connecting seas and oceans.

Inland Navigation Canals.—Ordinary inland navigation canals in England are mostly of uniform dimensions, 40 feet to 45 feet surface width, 25 feet bottom width, and 4½ feet depth of water. Experiment has shown that the degree of resistance offered by the water of a canal depends very largely on the relative dimensions of boat and canal and not so much on the weight carried. The minimum resistance occurs when the width on the water line is about four times that of the barge, and the area of a transverse section of the canal about six and a half times that of the immersed part of the boat. If these dimensions are not possible, the bottom width should at least be twice that of the largest barge, and the depth 1 foot to 2 feet deeper than the draught of the heaviest boat. The towing path, about 2 feet above water level, should leave room for two horses to pass each other. The sides should have a slope of 1½ ft. or 2 ft. per foot, and in porous soils the canal has its sides and bottom clay puddled with gravelly clay. On English canals it is estimated that an average loss of 2 inches per day occurs through leakage and evaporation. The feeding of canals is frequently a difficult problem, especially as the period of greatest evaporation, the summer months, is also the period of least supply. Reservoirs then have to be constructed at high levels.

As a canal consists of a series of reaches at different levels, some plan must be adopted for the transference of a barge from one level to another, and this may be done by (1) locks; (2) inclines; (3) lifts.

A lock is a watertight enclosure having a pair of gates at each end (head gate and tail gate), communicating with the respective levels of two reaches. The gates, opening in the middle, are made greater than the width of the lock, so that when they meet they form a slight angle and the pressure of the water forces them still more tightly together. After a boat enters the lock from the higher level the gates are closed, and sluices at the bottom of the other gate lower the water to the level of the lower reach. The other gates are then opened and the barge proceeds. The reverse operation is performed when ascending a canal. A flight of locks—an unbroken, step-like series—is used where difference of levels is very great; and where traffic is considerable and water is scarce a second flight lies parallel with the first, so that the water utilised for descending barges serves also for ascending vessels.

In some cases a barge is raised from a lower to a higher level on an inclined plane, being either lifted bodily out of the water on a wheeled cradle which is hauled up by a cable, or floated into a trough big enough to hold sufficient water to float the boat, and so hauled up. The operation is simplified by having a double line of rails and connecting the two troughs by cables in order that the weight of a descending barge shall assist in raising the ascending one.

Hydraulic lifts are sometimes used instead of inclines. A few minutes then suffice to transfer a barge from one level to another. *See* **Canal Lift.**

In England a large number of canals are in the hands of railway companies, which explains the neglect they have so long suffered. The fact that the railway companies own 30 per cent. of the canals in England, and yet earn but 14 per cent. of the total revenue from English canals, speaks eloquently of this neglect.

The following table gives some interesting figures concerning the canals of the United Kingdom:—

	Length.	Capital.	Traffic.	Net Profit.	Net Profit per Mile.
	Miles.		Tons.		
Canals not belonging to railway companies	2,768	£37,929,279	33,348,573	£598,260	£216
Canals belonging to railway companies	1,139	Unknown	6,009,820	46,237	40
Total	3,907	...	39,358,393	£644,497	£165

Within thirty years of the construction of the first English canal—the Bridgewater Canal, 1772—over 2,000 miles of canals were built in England and Wales. Unqualified success and huge dividends followed. Then came the railway mania. The year 1834 saw the construction of the last canal, and between 1845-48, 1,000 miles of canals passed into the hands of the railway companies. Since then the history of these valuable waterways is summed up in one word—stagnation. Barges disappeared, and weeds and fishes grew apace.

The Canal Traffic Bill, which has not yet got beyond a second reading, having been successfully opposed by the railway companies, provides for the abolition of railway control, and the purchase and management of navigable waterways by public canal trusts. This scheme was adopted by a majority of the Chambers of Commerce in 1904. If, however, canals are to regain their once flourishing position they will have to be widened and deepened, and other methods of haulage introduced. The horse must go. He is sadly out of date in these days of steam tugs and electric motors.

On the Continent the canal takes its proper place in the commercial life of the nations. Belgium ranks first in proportionate mileage. An average of well over half a million pounds a year has been spent on canals in that country during the last twenty-five years. Moreover, Belgium was one of the first countries to introduce electric traction; for more than 30 miles on the Charleroi Canal electric tractors run along the towpath, served by overhead wires. In France over one hundred million pounds have been expended on canals, many of them being entirely free of tolls, and constructed and maintained at national expense. The majority of French canals are of uniform depth, 6½ ft., and the locks are 126¼ ft. × 17 ft. In Germany and Austria, too, the expenditure of many millions has been sanctioned for the construction of new and improvement of old canals. In Germany the volume of canal traffic has increased greatly in recent years, and canal boats propelled by steam convey goods at less than one farthing per mile per ton. In 1905 the Prussian Diet sanctioned schemes involving the expenditure of £16,700,000 on new canals.

Ship Canals.—There is no more entrancing story than that of the herculean labours, heartbreaking difficulties, and tragic failures connected with the construction of the world's ship canals. Into all this we cannot, however, enter, and must rest satisfied with the following useful summary of the dimensions, cost, traffic, date of opening, &c., of the leading ship canals.

Suez Canal.—Through the Isthmus of Suez connecting the Mediterranean and Red Sea. Opened 1869. Length, 100 miles; depth, 30 ft.; surface width of 327 ft. for 77 miles, and 196 ft. for 22 miles; bottom width averages 229 ft. These were not the original dimensions, widening and deepening operations having been in progress since 1886. Cost £20,000,000. It crosses three lakes, and at intervals of 5 or 6 miles the canal opens out into sidings to allow large vessels to pass each other. Time

occupied in passage averages 18 hrs. 8 mins., but for vessels navigating by day only, the average is 23 hrs. 25 mins. For vessels paying additional dues the canal can be lighted up at night by electric light.

THE EXTENT TO WHICH THE VARIOUS COUNTRIES USE THE SUEZ CANAL.

Flag.	No. of Vessels.	Net Tonnage.	Per cent. of Vessels.	Per cent. of Net Tonnage.
United Kingdom	2,679	8,833,929	63·2	65·9
Germany . .	542	1,969,561	12·8	14·7
France . .	262	777,742	6·2	5·8
Holland . .	223	582,967	5·3	4·4
Austria-Hungary	135	454,606	3·2	3·4
Italy . . .	94	205,477	2·2	1·5
Russia . .	82	153,848	1·9	1·2
Norway . .	72	145,804	1·7	1·1
Spain . . .	29	88,427	0·7	0·7
Denmark . .	21	58,379	0·5	0·4
Turkey . .	43	44,756	1·0	0·3
America . .	17	24,436	0·4	0·2
Greece . .	17	24,385	0·4	0·2
Japan . .	6	21,463	0·2	0·2
Egypt . .	7	5,128	0·2	*
Belgium . .	2	4,521	*	*
Sweden . .	2	2,821	*	*
Portugal . .	3	2,530	0·1	*
Chile . . .	1	1,055	*	*

* Less than 1 per 1,000.

This table is for 1904, but is fairly representative of the extent to which the Canal is annually used by the nations.

THE SHIPPING, TONNAGE, PASSENGERS, AND RECEIPTS OF THE SUEZ CANAL.

Year.	No. of Vessels.	Net Tonnage.	Transit Receipts (Francs).	No. of Passengers.
1894	3,352	8,039,175	73,776,827	166,003
1895	3,434	8,448,383	78,103,717	216,940
1896	3,409	8,560,283	79,569,994	308,241
1897	2,986	7,899,373	72,830,545	191,224
1898	3,503	9,238,603	85,294,769	219,729
1899	3,607	9,895,630	91,318,772	221,348
1900	3,441	9,738,152	90,623,608	282,203
1901	3,699	10,823,840	100,386,397	270,221
1902	3,708	11,248,413	103,720,020	223,775
1903	3,761	11,907,288	103,620,268	195,232
1904	4,237	13,401,835	115,818,479	210,849

Manchester Ship Canal.—Constructed during 1887-94, and opened in latter year. Length, 35½ miles; depth, 26 ft., now being increased to 28 ft.; bottom width, 120-170 ft.; 60 ft. above sea level. Tidal locks at Eastham, and others at Latchford, Irlam, and Barton, with lifts varying between 14 ft. and 16½ ft., and measuring respectively 550 ft. × 60 ft.; 300 ft. × 40 ft.; 100 ft. × 20 ft. Banks are sloped 1 in 1 and pitched with stones. Estimated cost, £5,330,000; actual cost, £15,250,000. About 54,000,000 cub. yds. of earth were excavated.

The Kaiser Wilhelm, North Sea and Baltic, or *Nord-Ostsee* Canal, provides a short cut between the Baltic and North Seas, from Kiel to Brunsbüttel at the mouth of the Elbe. Constructed 1887-95. Of great strategic importance, as it saves a none too safe detour of 600 miles. Length, 61 miles; surface width, 200 ft.; bottom width, 72 ft.; depth, 29 ft. Cost £8,000,000, and 106,000,000 cub. yds. of earth were excavated.

Amsterdam Canal, connecting Amsterdam with the North Sea. Constructed 1865-76. Length, 16½ miles; surface width, 187 ft.; bottom width, 89 ft.; depth, 23 ft. Cost £2,600,000.

Among minor ship canals are the Isthmus of Corinth Canal opened in 1893; saves two days in voyage from Adriatic to Black Sea. It is 4 miles long, 26 ft. deep, bottom width 72 ft. Middle portion flows through a cutting in rock 285 ft. high. Cost £3,000,000. The Cronstadt or Pontileff Canal, 1877-84, connects St Petersburg and Cronstadt. Length, 17½ miles; depth, 22 ft.; and bottom width, 207-275 ft. Cost £1,300,000.

The ill-fated *Panama Canal* scheme was designed to cut through the Isthmus of Panama at its narrowest part, and would have been 46½ miles long, 124 ft. surface width, 72 ft. bottom width, 27 ft. deep, except in the deep cutting through the Culebra range. In 1894 a new company was formed to resume the construction of the Panama Canal, but sold its rights to the United States, and the latter country has now taken the construction of the canal in hand. The proposed Nicaragua Canal would connect the lake of that name with the San Juan river, and the Atlantic.

Many schemes for the construction of new ship canals are in the air. The more important proposals are to connect Paris and Brussels with the sea; to join the Baltic and Black Seas by

. a 1,000 miles long canal from Riga to Kherson; to cut through the peninsula of Florida; to pierce the Isthmus of Perekop which unites the Crimea with the mainland and so connect the Sea of Azov with the Black Sea; and to cut through the island of Rameswaram which blocks the passage between Ceylon and India.

Cancellation.—In mathematics is the process of striking out common factors in order to simplify and facilitate calculation. Thus $\frac{14}{21} = \frac{7 \times 2}{7 \times 3}$, 7 being common to numerator and denominator may be struck out without altering the value of the fraction: thus $\frac{14}{21} = \frac{2}{3}$. In order to find the greatest number by which a fraction may be cancelled it is necessary to obtain the **Greatest Common Measure.** When thus cancelled the fraction is said to be in its lowest terms, and numerator and denominator are "prime" to each other, *i.e.*, no number higher than 1 can be divided into them. As a rule, however, fractions are cancelled by successive divisions. Thus :—$\frac{420}{480} = \frac{42}{48}$ (cancelling by 10), $= \frac{7}{8}$ (cancelling by 6).

The following conditions of divisibility are worth memorising:—A number is divisible by 2 when it is an even number; by 3 when the sum of its digits is divisible by 3; by 4 when the last two figures are divisible by 4; by 5 when the unit figure is 0 or 5; 6, when the number is even and the sum of its digits is divisible by 3; by 8, when the last three figures are divisible by 8; by 9, when the sum of the figures is divisible by 9; by 10 when the unit figure is 0.

The process of cancelling plays an even more important part in Algebra than in Arithmetic. The greatest common measure, or, as it is often called, the highest common factor, is first found and then divided into numerator and denominator. Thus in the fraction, $\frac{18a^5bc^3}{24a^3b^2c^3}$ it is evident that $6a^3bc^3$ is common to numerator and denominator. Dividing by this quantity we find that $\frac{18a^5bc^3}{24a^3b^2c^3} = \frac{3a^2}{4b}$. Again :—$\frac{a^2 - x^2}{a^2 - 2ax + x^2} = \frac{(a-x)(a+x)}{(a-x)(a-x)}$. Striking out the common factor, $(a-x)$:—$\frac{a^2 - x^2}{a^2 - 2ax + x^2} = \frac{a+x}{a-x}$. *See also* the articles, **Factors**, and **Fractions.**

Candle Power.—Candle power is the standard by which the light given by all illuminants is measured. All illuminants are spoken of as giving so many candles power, whether they afford a very small, or very large quantity of light. The standard is a sperm candle burning at the rate of 120 grains per hour. The modern candle of commerce gives very much more than the light of a standard candle. Hence it is usual for those who are constantly employed in measuring the candle power of illuminants to arrange a standard for themselves, which bears a certain ratio to the theoretical standard candle. All the gas companies have a standard lamp, in the form of an Argand burner, burning pentane, which is carefully tested at frequent intervals, and the conditions of burning of which are kept as closely as possible constant. With illuminants which burn in air, it is difficult to maintain the candle power and the consumption of the fuel it burns constant, as so much depends upon the draught. Similarly, open arc lamps vary with the surrounding conditions. Electrical firms who make incandescent lamps have a standard incandescent lamp, of each candle power that is made, by which every lamp that leaves the works is or should be tested.

Another difficulty that arises in connection with nearly every form of illuminant in which a large quantity of light is given out by one lamp is, the light varies according to the position of the observer from it. With arc lights, using continuous currents, there is very little light given out directly above and directly below the arc, while with both alternate and continuous current arcs, the light given out is principally between planes at angles of thirty degrees with the vertical and thirty degrees with the horizontal. With the usual form of incandescent electric lamp also the light is distributed all round the lamp, very little being given out below it and none above. This difficulty is overcome by taking photometrical measurements of the light given by the lamp under test in every position, plotting them in a

curve around the source of light, and taking the average, which is termed the mean spherical candle power, that is to say, the mean of all the candle powers at every point all round the sphere of which the source of light is the centre. The light given by any lamp varies as the square of the distance of the object illuminated from it, and this affords a ready means of comparing the candle power of any two illuminants. The shadow of a stick cast by each illuminant is arranged to be equal, and the distance measured from each lamp to the stick; or the distance from each lamp at which a certain print can be read may be taken; the candle powers of the lamps are in the direct ratio of the squares of these distances.

Cantilever Bridge.—A bridge the arms of which are self-supporting from the abutments. The best known example is the Forth Bridge, Fig. 107, Plate VIII. The span of these measures 1,710 feet in the clear. A longer bridge is one over the St Lawrence River at Quebec, with a single span of 1,800 feet.

The design of cantilever and central girder embodied in the famous Forth Bridge is not new. It is found in ancient architecture, in some ancient bridges, and in embryo in all continuous girder bridges. The latter may be considered as cantilevers supporting a central girder at the points of contrary flexure, as has been demonstrated by many writers. Actually, however, the continuous girder has until recently been preferred to their severance at the point of flexure, and the breaking of the continuity, and of the dimensions of the girders.

The first railway bridge in which the cantilever and girder system was carried out was erected in 1876, over the Warthen near Posen. It is of 148 feet span. No other was built until the Forth Bridge embodied the design on a colossal scale, since which others have been constructed on similar lines. But the Forth Bridge was nevertheless an unique structure in all its details, owing nothing whatever to previous designs except the broad principle. It was designed with a view to fulfil all the requirements of a long railway bridge subject to heavy traffic, and it has amply fulfilled these, and is the finest railway bridge in the world.

The cantilevers and central girders are designed with a view to the best possible distribution of material consistently alike with strength, stability, lightness. Moreover the design is such that each successive portion was built out by overhanging from the portion last erected, and braced with the permanent bracing as the work proceeded. Very little temporary staging was therefore required beyond that wanted by the riveters, who riveted the sections in place. The steel tubes or columns are 350 feet in length, and some as large as 12 feet in diameter. These, with the bracings, were all prepared in sections in the workshops, and the staging for the erecters and for the cranes went out along with the successive lengths. The cantilevers spread out in plan as well as in elevation, and the greatest weight was low down on the piers, only 18 feet above high water. The incomplete work was so rigid that no hurricane could have carried it away. The rigidity and freedom from vibration is so excellent that the rolling load of a 400 ton train will not deflect the bridge more than an inch, in a span of 1,730 feet, and a wind pressure of 30 lb. per foot would only curve the bridge laterally to the extent of 6 inches.

Cantilever Crane.—Cantilever cranes are employed where it is undesirable or impossible to handle a load by a crane directly on the spot, and where a good range of movement is necessary. The cantilever arm is either of plated or lattice type, or else is stiffened and supported with tie rods from posts about the centre of the crane. The **Block-Setting Crane** is an example of the first named, and the lighter Brown types instances of the second. A distinction between these designs is that the Titans have a fixed balance or counterweight, hung on the short tail of the superstructure, the engines and boiler forming a portion of the balance, while the Brown has double arms, and a movable weight running on a trolley, controlled by ropes connected to the lifting trolley, so that the balance is automatically preserved at all radii. The trolley is travelled in both the cantilever types named by ropes from the engine or motor, the lifting ropes being also carried out similarly.

Cantilever cranes are of three main types: the carriage or frame travelling, with hoisting and racking motions to trolley; or having a revolving jib, also with hoisting and racking; and all these

combined in one machine. For many purposes it is unnecessary to have a slewing or revolving motion, as when the frame travels along parallel with the areas to be covered; but when the crane has to be fixed, a rotary movement is generally essential. In this case the entire circular space within the range of the jib is under the reach of the hook. The usual horizontal jib position is sometimes changed for a sloping attitude, to suit particular work, an example of which is seen in Fig. 108, Pl. VIII., a Brown crane employed for canal excavation. The low end dips down over the excavated area, while the opposite extremity carries the material up over a heap and dumps thereon. The use of a grab in this particular case illustrates one of the most useful applications of the cantilever crane, because of the large area which can be treated without having the crane in the way of workmen, and having to lay rails frequently as the work proceeds. Fig. 109, Pl. IX., shows two 15-ton cranes at the Barrow-in-Furness shipyard of Messrs Vickers, Sons, & Maxim, Ltd. The arrangement is such that two ships, one on either side of the crane gantry, are covered, both lengthwise and crosswise, by the longitudinal movement of the crane frame, and the transverse motion of the trolley. These Brown cranes are either steam or electrically driven, the mechanism in each case being located on the foot of the frame, instead of on the trolley, so that the latter itself is of very light construction, a feature conducing to rapid movement, and light disposition of the material in cantilever arms.

A special type of cantilever crane employed for coal handling from vessels has a hinged jib or apron, reaching out over the water. When vessels are being brought alongside or moved away, this apron is folded upright, to clear the masts or funnels, and when the ship is moored, the horizontal position is again imparted, so that the hatches are brought within range.

Canting Fence.—A fence or guide used chiefly on the tables of machine saws and jointers, which is not fixed permanently in a vertical position, but can be canted or inclined to an angle and held by a pinching screw in the position required. It consists usually of a base plate which always remains flat on the table, and a side plate which is hinged in some way to the base and provided with a quadrant or other means by which it can be held at the angle required. When in the vertical position it is at its limit in the inclination of its upper part toward the work; the angles being obtained by swinging it back so that its working face forms an obtuse angle with the working face of the table. It is used for sawing or planing at an angle with the face of the work which is kept back against the fence.

Caoutchouc.—*See* **Indiarubber.**

Cap.—In its most common meaning it signifies the upper detachable portion of a shaft bearing which retains the shaft in place, either directly or through an intermediate brass lining.

Capillary Attraction.—If a glass tube of wide bore is immersed in water, the liquid stands inside the tube at the same level as that outside. If a tube of narrow bore be substituted, the water is found to rise to a higher level than that outside the tube, and the narrower the bore the higher does the water rise—the height varying inversely as the radius of the tube. This is explained by the theory that the surface layers of all liquids behave as films, as in the common example of a soap bubble. In such a liquid film there exists what is known as a surface tension causing the upper layers of the liquid to act like an elastic membrane. In the case of the surface tension in a soap bubble it has been proved that the air pressure inside (on the concave surface) is greater than that outside (on the convex surface). In capillary tubes the concave side of the water is always upwards, hence pressure immediately below its surface is less than the pressure of the atmosphere outside, and so the water is able to rise to a higher level than that surrounding the tube.

The lubrication of bearings by feeding the oil through a filament of cotton wick is an everyday example of capillary attraction.

Capstan.—A machine fitted on board ship and dock walls for hauling or warping a rope for mooring purposes, hence often termed a warping capstan. There are four types, the hand, the steam, the electric, and the hydraulic, and a subdivision is that into single, and double purchase.

Hand Capstans.—These are mounted on a



Fig. 107.—Forth Bridge. Example of Cantilever and Girder Bridge.



Fig. 108.—Cantilever Crane on Canal Cutting. (Brown Hoisting Machinery Co.)

To face page 138.

base which usually carries the pawl holes. The turning is done by handspikes inserted in holes in the head. These holes properly have their axes set at an upward angle from the horizontal, so that the bars have a rake upwards and are at a convenient height for the men to handle. The capstan base is bolted to the deck or floor, and a centre spindle, keyed in the base, connects it with the upper part. Such capstans are fitted also with internal gear for double purchase. The bodies are sometimes cast plain, but generally with vertical ribbings (whelps) to increase the bite of the rope. Sometimes whelps of wood are fitted.

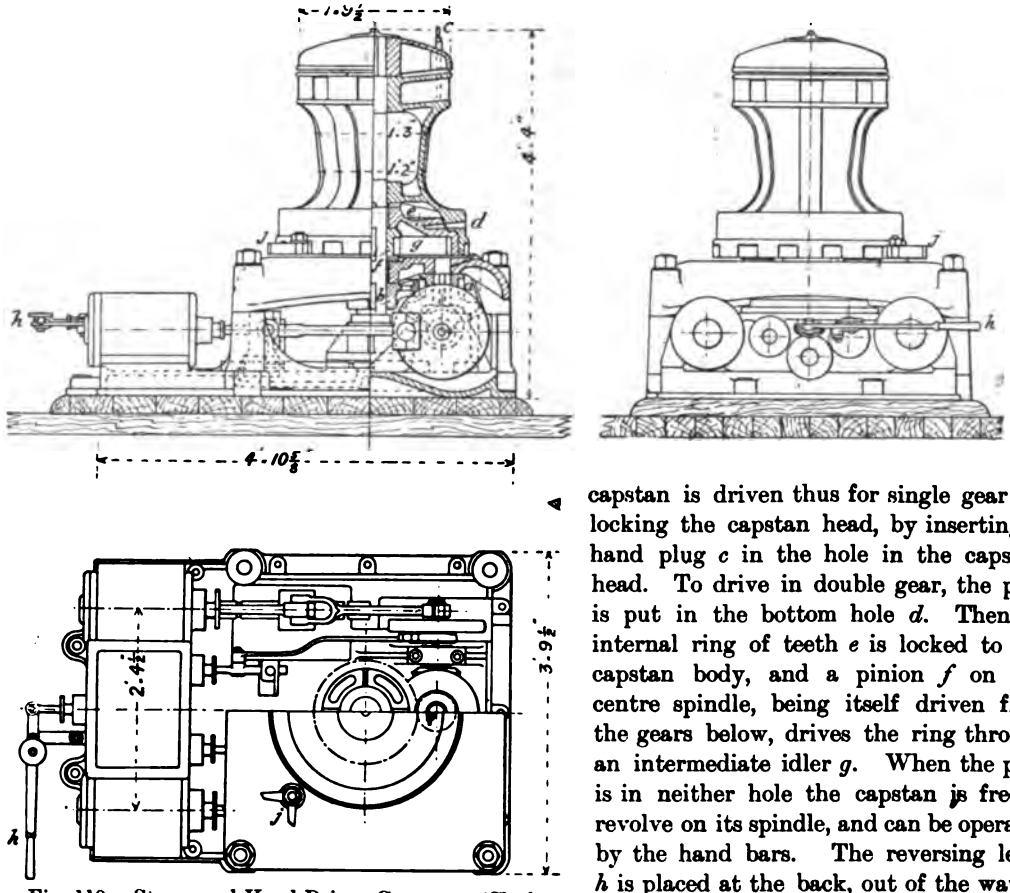


Fig. 110.—Steam and Hand Driven Capstan. (Clarke, Chapman, & Co., Ltd.)

Steam Capstans.—These are combined with hand operation by casting holes for bars in the top. They are therefore hand-pattern capstans mounted on an engine bed with suitable connecting gear. A good example of this type is shown in Fig. 110. It is driven by a pair of 7-inch by 10-inch cylinder engines. This capstan is worked by bevel gears from the crank shaft, but frequently worm gears are used, as being noiseless, and self pawling in every position.

On the vertical shaft that carries the driven bevel wheel there is a spur pinion *a*, driving a wheel *b* keyed on the centre spindle, and the capstan is driven thus for single gear on locking the capstan head, by inserting a hand plug *c* in the hole in the capstan head. To drive in double gear, the plug is put in the bottom hole *d*. Then an internal ring of teeth *e* is locked to the capstan body, and a pinion *f* on the centre spindle, being itself driven from the gears below, drives the ring through an intermediate idler *g*. When the plug is in neither hole the capstan is free to revolve on its spindle, and can be operated by the hand bars. The reversing lever *h* is placed at the back, out of the way of the ropes. It operates a controlling valve to the slide-valves instead of link motion. The pawl *j* is double, to be used in either direction of drive.

Electric Capstans. — The advantage which these have over the steam-driven ones is that the power consumed corresponds with the varying amounts of work done. An example is shown in Fig. 111. The following is a description of it :—

The capstan is mounted on a box which

encloses the motor and gears. The electric motor drives the capstan barrel through worm and wheel, and spur pinion and wheel, and is capable of exerting a pull of 10 tons at a speed of 20 feet per minute, or 5 tons at 40 feet per minute, when supplied with continuous current at 250 volts. The motors, controller, and gearing are fitted inside the cast-iron box, made water-

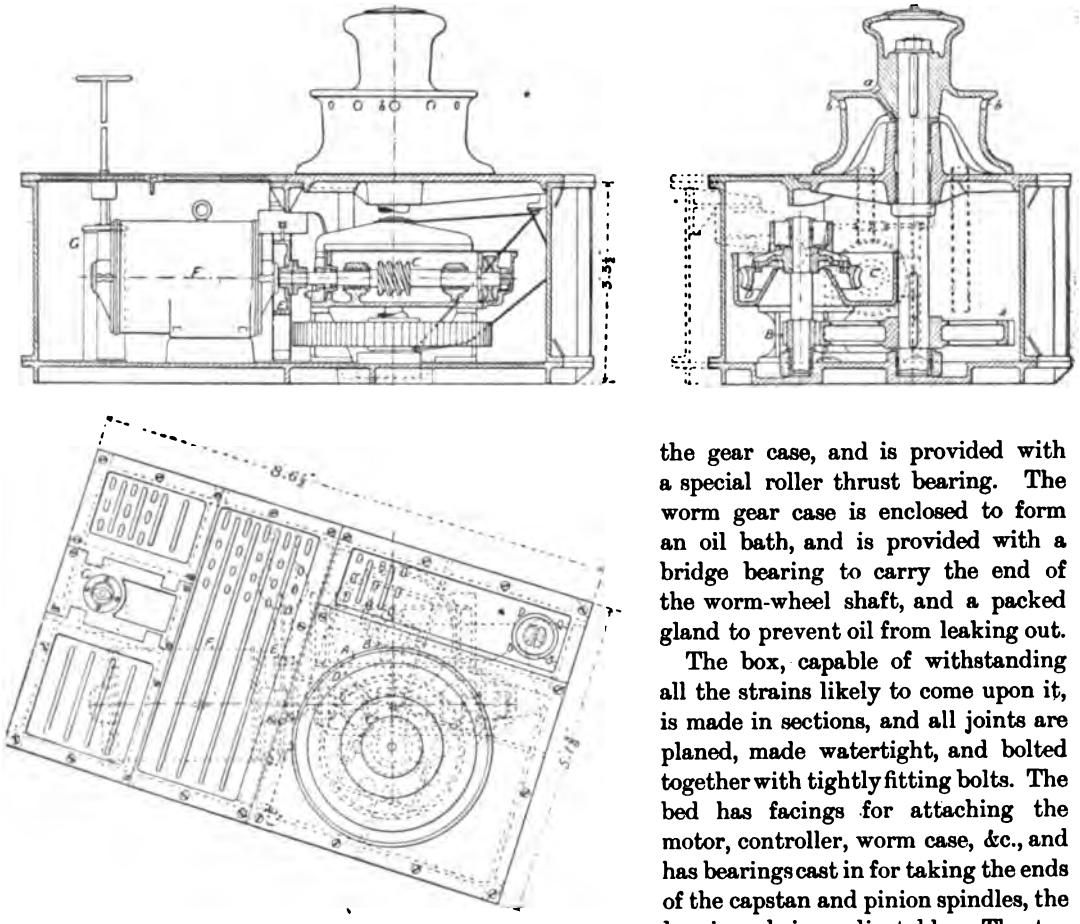


Fig. 111.—Electrically Driven Capstan. (Clarke, Chapman, & Co., Ltd.)

tight, and suitable for dock work. The spindle is of forged steel machined all over, and with the end screw cut and provided with a nut to counteract the tendency of the capstan barrel to lift when under load.

The spur gearing is of cast steel, the main wheel A is keyed to the capstan spindle, and gears with its driving pinion B, keyed to the worm-wheel shaft. The worm C is forged solid with its spindle, and coupled direct to the motor, and drives the machine-cut worm wheel D, having a gun-metal rim securely bolted to the face of a strong cast-iron centre, keyed to the same shaft as the pinion B, which it drives. The worm runs in adjustable bearings formed in the gear case, and is provided with a special roller thrust bearing. The worm gear case is enclosed to form an oil bath, and is provided with a bridge bearing to carry the end of the worm-wheel shaft, and a packed gland to prevent oil from leaking out.

The box, capable of withstanding all the strains likely to come upon it, is made in sections, and all joints are planed, made watertight, and bolted together with tightly fitting bolts. The bed has facings for attaching the motor, controller, worm case, &c., and has bearings cast in for taking the ends of the capstan and pinion spindles, the bearings being adjustable. The top consists of cast-iron chequered plates secured to the body by gun-metal bolts, and provided with a packed gland for the controller spindle, having a portable cover for use when the capstan is not running. The top bearing is made so as to form a portion of the box, secured to the box flanges on three sides, and to a strong cast-iron stretcher on the fourth side. Doors are

fitted in the top for easy access to the motor and gearing.

The capstan top bearing is lubricated through a channel *a*, cast in the capstan barrel, and provided with a plug; all bearings within the box are lubricated by oil pipes taken to an oil box placed in the main box, a cover being provided in the top plates for easy access for filling the same. To ensure the box being kept cool and dry a system of ventilating pipes is fitted, and holes *b* are cast in the capstan barrel to permit of free circulation of air.

A brake E is fitted to the motor coupling capable of holding the maximum load. It is automatic in its action, the brake being taken "off" magnetically, and put "on" by means of a spring.

The motor F is of the four pole enclosed type with slot wound drum armature, and provided with self-oiling bearings. It is fitted with carbon brushes capable of carrying the full current, without heating and without sparking. It is capable of developing 23 BHP. at 250 volts when running at about 600 revolutions per minute, and the temperature rise is guaranteed not to exceed 100° Fahr. above that of the surrounding air after a continuous run of one hour at the specified full load. The controller G is of the foot pedal type, and is operated by a portable pedal projecting above the box (if desired the controller can be arranged to work by hand lever). The pedal is connected with a dashpot to prevent too rapid movement in starting, but which allows the switch to return quickly to the "off" position. The controller is provided with an automatic circuit breaker, which comes into action in the event of the motor being too heavily loaded, the circuit breaker being fitted in a convenient position outside the gear box. An Hydraulic Capstan will be found under **Hydraulic Engine.**

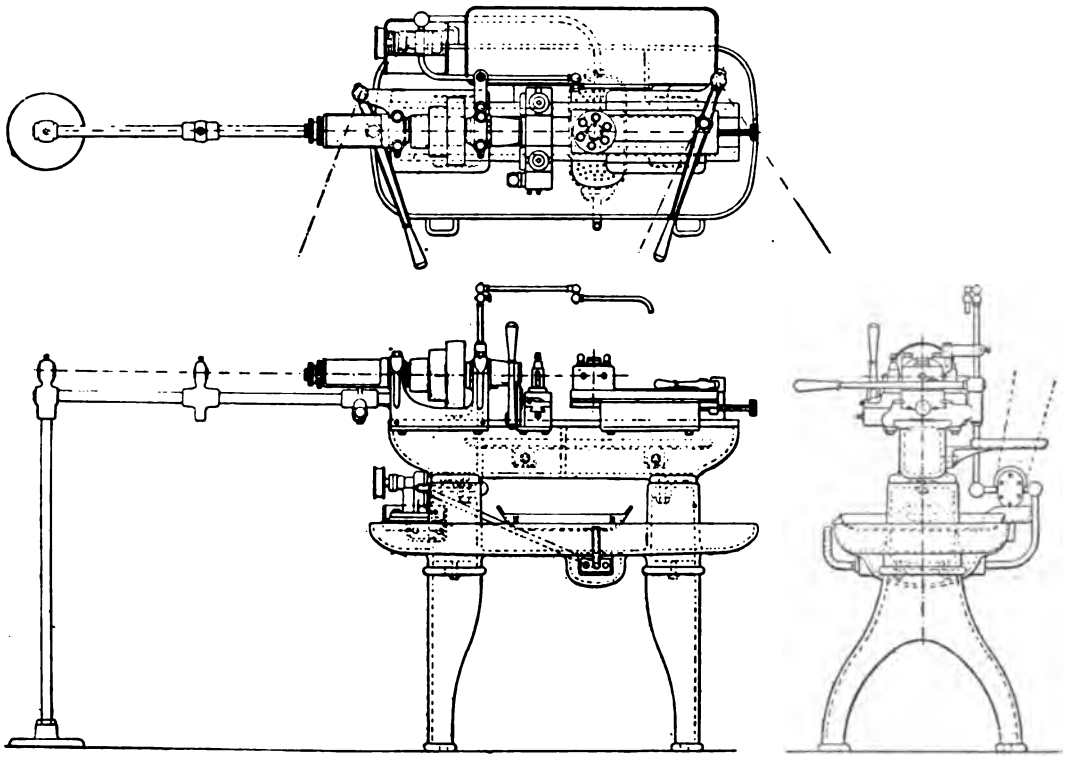


Fig. 112.—Capstan Lathe. (A. Herbert, Ltd

Moulding.—Capstan bodies are moulded from full patterns when for standard requirements, but from loam patterns for occasional sizes. Wooden patterns are properly rammed upright

with horizontal joints, those of loam on the side with the axis in a horizontal position. In this case the bar holes are made in ring segmental cores. The centre core is rammed in a box in small and standard work, but swept up in loam on a bar, with core plates in large sizes, and for odd orders.

Capstan Lathe.—The capstan rest has perhaps been the most potent factor in workshop economies both on account of its rapidity of production and the uniformity of results obtained. The difference between changing tools on the ordinary slide rest and the instant rotation of a capstan is without comparison, so that wherever repetition turning has to be done the capstan may be used generally with great advantage.

There are two main types of capstan lathe—one where the rest stands to one side of the centre, the other in which the rest lies with its axis centrally. The word turret is often applied indiscriminately to both of these forms. The chief difference involved is that the tools are dissimilar for use in the side-set, and the centrally-set capstan; the former being like ordinary lathe tool-holders, while the latter are of more special pattern, including box-tools, &c. An example of the side-set capstan will be found under **Open-Spindle Capstan Lathe**, so that it need not be repeated here.

Fig. 112 is a good example of a capstan lathe which is representative of the type. This machine takes $\frac{9}{16}$ bar through the spring chuck; the height of centre is $4\frac{5}{8}$ in., stroke of capstan 3 in. The bed has a solid or flush top, and stands on legs cast with a tray. The latter has a strainer through which the oil flows into a well, from which it is pumped up again over the work. The capstan and its slide are clamped where desired upon the bed, and the position of the cut-off rest can be also adjusted.

The details of the headstock and the wire feed are seen in section in Fig. 113. The spindle A runs in the bearings B, B, fitted with caps and half brasses; the cone pulley C is not keyed, but is forced upon the conical shoulder of the spindle by a ring-nut, thus avoiding any tendency to bend or strain the spindle. End-thrust is taken up by a ring of balls adjacent to the rear bearing. The chuck mechanism comprises a long tube D inside the spindle, having a conical nose split in three places, so that when forced outwards the contact with the cone inside the closer E causes the nose to grip the bar. The dogs F, F, thrust D endwise when the collar G is slid along, and its tapered end forces out the extremities of F, F, so that their toggle portions press upon the end of D. The sliding of G is effected by the boss H, which is moved to and fro by the long pivoted lever seen in the general view, Fig. 112. This movement also serves to feed the bar through the chuck every time a piece has been produced. The sliding ratchet bar which is drawn along as H moves, travels the holder K, lightly gripping the bar, and so moves the latter through the chuck. A catch allows K to be disconnected from the ratchet, and moved back to take a fresh hold on the bar. The outer support L serves to steady the bar when it projects a long distance.

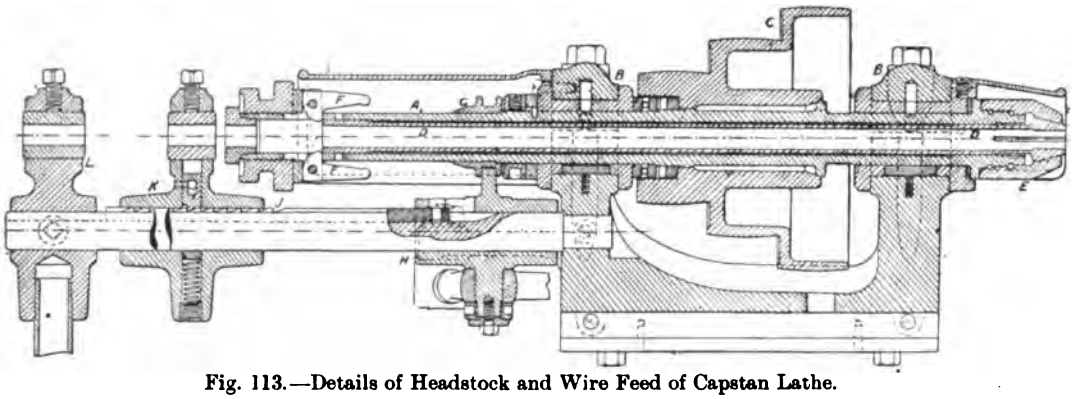


Fig. 113.—Details of Headstock and Wire Feed of Capstan Lathe.

Details of the capstan are seen in Figs. 114. The slide N is reciprocated by the handle O pivoted on the base piece P. The length of travel is limited by the stop screw Q. The turret is revolved automatically on the backward stroke by one of the ratchet teeth seen dotted at R catching against the lever S, fastened

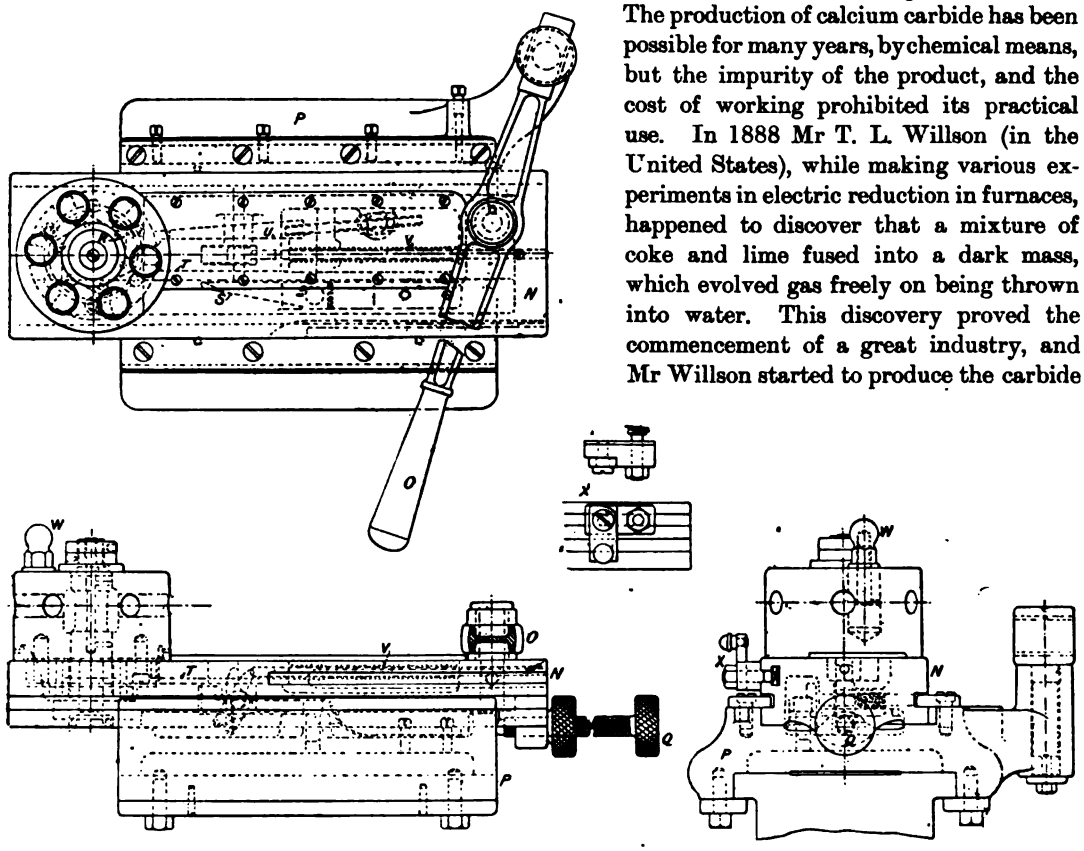


Fig. 114.—Details of Capstan Lathe.

and pivoted in the base piece P. The locking is performed by the bolt T fitting by its tapered end into either one of the recesses in the capstan base; to prevent slackness developing, T is kept up to a fit in the slide by the adjustable taper gib U. The long spiral spring V presses T into place in the locking holes. The tools are held in the capstan by bolts W, the heads of which bear by a concave corner upon the circular shanks. An additional dead stop is fitted to the capstan slide as seen at X, being thrown downwards to strike the end of the base P, adjustability being secured by the use of the T-slot running along the slide so that the stop may be bolted at any position.

The cut-off slide is of plain form, carrying two tool holders and moved to and fro by a lever and slotted link. Other special types of Capstan Lathes will be found under various heads.

Carbide of Calcium.—CaC_2. Sp.Gr. 2·262. The production of calcium carbide has been possible for many years, by chemical means, but the impurity of the product, and the cost of working prohibited its practical use. In 1888 Mr T. L. Willson (in the United States), while making various experiments in electric reduction in furnaces, happened to discover that a mixture of coke and lime fused into a dark mass, which evolved gas freely on being thrown into water. This discovery proved the commencement of a great industry, and Mr Willson started to produce the carbide in quantity. A large number of plants are in operation all over the world, water-power installations constituting the majority, because of the necessity of getting the current cheaply. A large proportion is made at Niagara.

Various types of furnaces have been devised, into which designs we cannot enter; the principle resembles that of the Carborundum furnace, the mass being heated up by the passing of current from terminals. The chief item in carbide manufacture is not the cost of the constituents, but that of the current; at the same time a certain standard of purity must be

ensured. The coke must not contain a large amount of ash, nor the lime, sulphate, phosphate, sand or alumina, because of the objectionable sulphur compounds introduced. A small percentage of these is unavoidable in commercial carbide however. For the utilisation of carbide *see* **Acetylene.**

Carbolic Acid, or **Phenol** (C_6H_5OH), is obtained by distilling coal-tar. Various gases and volatile substances are given off as the temperature rises, those which pass over between 150° to 240° Cent. being reserved for the preparation of Phenol. In its pure state it is a white, crystalline solid, turning slightly red on exposure to the atmosphere; it readily absorbs water from the atmosphere, and is also easily liquefied by addition of water; possesses a powerful odour resembling creosote, and a burning taste; is readily soluble in ether, alcohol, chloroform, acetic acid, and volatile oils; specific gravity, 1·09 at 0° Cent., melting point 35° Cent., boiling point 183° Cent.

Carbolic acid, strictly speaking, is not an acid, but is more nearly related to the alcohols. It is for example neutral to test papers although it forms carbolates or phenoxides in combination with alkalies. It is used in the preparation of picric acid or trinitrophenol, $C_6H_2(NO_2)_3OH$, a constituent of several explosives. The uses of carbolic acid as an antiseptic and deodoriser are well known.

Carbon (C. 12) is one of the most widely diffused of elements. It occurs in the free state as the diamond, graphite, and in a less pure state as coal; in combination with oxygen it forms carbon dioxide, CO_2, always present in the atmosphere; in the earth's crust carbon occurs abundantly in carbonates, limestone, dolomite, and ironstone; finally it is characteristic of all animal and vegetable life. The natural forms of carbon, the diamond, graphite, &c., are crystalline in form, but other varieties of carbon are prepared artificially and are amorphous, like wood charcoal, coke, bone-black, and lamp-black from either animal or vegetable oils. *See* **Charcoal.**

As regards the various properties of the allotropic modifications of carbon—the diamond is a non-conductor, while graphite is a good conductor of heat and electricity; charcoal and diamond occupy the two extremes of combustibility, with animal charcoal, coke, lamp-black, and graphite in the intermediate stages. The peculiar power of absorbing gases possessed by charcoal renders it useful as a disinfectant. Used in sewers, in respirators, or sprinkled over decaying organic matter, fetid gases are immediately absorbed and oxidised in the pores of the charcoal. Carbon is also an essential constituent in water filters.

Carbon in different forms is also used extensively in various arts and manufactures. The use of **Animal Charcoal** in decolourising processes is referred to under that title, and also under **Case Hardening.** A particularly dense form of carbon is prepared artificially for use in galvanic batteries, a mixture of powdered coke and coal being heated in a mould, then soaked in tar, and when dried, reheated in a crucible until it is practically non-porous, and a good conductor of electricity. The carbon rods used in the **Arc Lamp** are made from a baked paste of powdered coke. The diamond is invaluable for cutting and drilling, while the carbonado of Brazil, an imperfectly crystallised form of diamond is used for turning down and truing emery wheels and for the heads of rotary diamond drills used in rock boring. The friability of graphite renders it extremely useful to the engineer as a lubricant. The distinctive colour and appearance of grey cast iron are also due to the minute particles of graphite in the metal, best seen in examining a fractured surface, or iron turnings. *See* **Cast Iron.**

Carbon as a Fuel.—Carbon is the only commercial fuel, excepting hydrogen, with which it is usually more or less combined. Existing also as the diamond and as graphite, the fuel forms of carbon are anthracite coal, and wood charcoal, both of which are nearly pure carbon. With hydrogen in combination, carbon is found in all other coals, of which, indeed, it is the chief constituent, and as petroleum, alcohol, and wood. The calorific capacity of amorphous carbon burned to CO_2 is 8,137 calories per kilogram = 32,285 B.Th.U., or 14,647 B.Th.U. per pound = 3,691 cals. The atomic weight of carbon is 12, its specific heat from 0·1468 to 0·285. It vaporises at 3,600° Cent. = 6,512°

Fahr. It forms two oxides, namely, carbonic oxide, and carbonic acid, CO, and CO_2.

Burned to CO it produces 4,415 B.Th.U. per pound, or 2,453 calories per kilogram.

The temperature of combustion in air is 1,485° Cent. = 2,705° Fahr. In oxygen it is 4,292° Cent. = 7,757° Fahr., when only burned to the carbonic oxide, CO.

Burned to CO_2 the temperature, theoretical, is in air 2,753° Cent. = 4,988° Fahr. In oxygen it is 10,226° Cent. = 18,440° Fahr. Each pound of carbon requires 1·33 lb. of oxygen for the first oxide, and 2·66 lb. for the second oxide. If burned with an insufficient supply of air, carbon only forms its first oxide, and less than a third the full calorific value is obtained.

The only sources of carbon as fuel are the stored fossilised plants of past ages, now known as coal, and the petroleums, the exact origin of which is doubtful. Coal is perhaps being used up faster than it is being formed, so that the ultimate fuel of the world may be wood. Seeing that the first oxidation of carbon produces 4,415 B.Th.U., and that a further 10,232 B.Th.U. are formed by the second oxidation, it is usual to speak of the difference, or 5,817 B.Th.U., as the latent heat of vaporisation of carbon. Now, since the complete oxidation of solid carbon produces 14,647 B.Th.U., we have 14,647 + 5,817 = 20,464 B.Th.U. as the calorific value of carbon if vaporised, and since carbon in the form of hydrocarbon gas is already vaporised, the burning of a gas should produce 20,464 B.Th.U. per pound of its carbon contents, in addition to the heat proper to the hydrogen. That this effect is not always produced is due to the fact that in the formation of compound gases heat may be generated, the formation of a hydrogen-carbon compound being, like combustion, merely a chemical action. The calorific power of fuel cannot, therefore, be exactly calculated from the chemical composition, but much has yet to be learned in regard to endothermism and exothermism.

Methane or CH_4, which contains nominally five volumes of gas, assuming carbon as a gas, only occupies a space of two volumes, whence it may be perceived that the hydrogen at least is much compressed, and must re-absorb heat when burned to water, when it will occupy four volumes. Hydrocarbon gases and vapours, when heated and suddenly cooled, are dissociated, with the formation of soot or solid carbon. Carbon fuels burn with the shortest flame when their hydrogen in combination is least in amount. Hence the comparative smokelessness of Welsh coal, and the total smokelessness of coke, charcoal, and anthracite, which consist only of carbon with some mineral impurity.

Carbonate.—Carbonates are salts formed by the union of carbonic acid (H_2CO_3), with a base. Two series of salts are formed: (*a*) in which both the atoms of hydrogen are replaced as in M_2CO_3, (*b*) in which only one atom is replaced as in $MHCO_3$. The former are neutral, the latter acid. The acid carbonates are sometimes called bicarbonates. Carbonates are remarkable for the ease with which CO_2 may be liberated even by dilute acids. The carbonates of the alkaline metals are soluble in water, those of the other metals are insoluble. The following are the names of some of the most important carbonates with their chemical formulæ:—

Potassium, K_2CO_3.
Soda (neutral carbonate), $Na_2CO_310H_2O$.
Sodium bicarbonate (acid carbonate), $NaHCO_3$.
Ammonium carbonate, Am_2CO_3.
Ammonium bicarbonate, Am_2HCO_3.
Lead, $PbCO_3$. Manganese, $MnCO_3$ (as manganese spar).
Iron, $FeCO_3$ (as the cupric carbonates).
Calcium (in chalk, limestone, marble, calc-spar), $CaCO_3$.
Magnesium, $MgCO_3$ (as magnesite).
Zinc, $ZnCO_3$.

Carbonate of Lime, or Calcium carbonate, $CaCO_3$, occurs abundantly in a crystallised form in marble, calc-spar, and arragonite, and in an amorphous state in limestone and chalk. It is held in solution by fresh and salt water, and enters largely into the composition of coral, of egg-shells, and the shells of mollusca. Its chief interest, however, lies in its injurious action in furring up boiler tubes and throwing down deposits on boiler plates. In pure water $CaCO_3$ is almost insoluble, but where the water contains carbonic acid gas, carbonate of lime is

easily dissolved; (1·797 vol. of carbonic acid gas are dissolved by 1 vol. of water at 0°, and ·901 vol. at 20°). Not only does the falling rain absorb a larger proportion of carbonic acid, but it is estimated that there are in the interstices of the soil about 250 times the quantity of carbonic acid gas present in the atmosphere. Water is thus able to dissolve large quantities of carbonate of lime. When the water is boiled, however, carbonic acid gas is driven off, and $CaCO_3$ is deposited on the bottom and sides of the vessel, decreasing the degree of conductivity of heat, and so demanding a greater consumption of fuel, to say nothing of the choking of narrow pipes and tubes and the consequent increased danger of accidents in boilers. This *temporary* hardness of water, due to the presence of calcium carbonate, must not be confused with the *permanent* hardness (not removable by boiling) caused by the presence of calcium sulphate, $CaSO_4$. *See* **Boiler Scale, Clarke's Process Feed Waters.**

Carbonate of Soda is the neutral sodium carbonate, commonly called soda. It occurs naturally in Hungary as an efflorescence on the soil, and is also present in the water of several lakes in different parts of the world. It was formerly obtained from the ashes of sea plants, but these insufficient sources have been discarded, and the manufacture of sodium carbonate from common salt, NaCl, is now carried on, on a vast scale. The alkali works of Great Britain use upwards of 700,000 tons of salt annually for the production of soda. There are two processes, the Ammonia-soda process, and the Leblanc process, named after its inventor.

The Ammonia-soda Process.—This, the latest and most widely adopted process, is based on the fact that when ammonia gas, NH_3, and carbon dioxide, CO_2, are passed into a solution of common salt, NaCl, sodium bicarbonate, $NaHCO_3$, is precipitated, and ammonium chloride (sal-ammoniac), NH_4Cl, remains in solution:—

$$NH_3 + CO_2 + NaCl + H_2O = NaHCO_3 + NH_4Cl.$$

The ammonium chloride is treated with lime so as to liberate the ammonia, which may thus be used again and again:—

$$2NH_4Cl + Ca(OH)_2 = CaCl_2 + 2NH_3 + 2H_2O.$$

From this it will be seen that the chlorine of the salt now appears as calcium chloride, which is thrown aside. The bicarbonate, $NaHCO_3$, is dried and heated, and so reduced to the carbonate.

The Leblanc, or *Salt-cake process*, discovered in 1793, is divided into two stages. In the first, common salt is treated with sulphuric acid in a salt-cake furnace. Hydrochloric acid gas is given off in great quantities, and sodium sulphate is formed—

$$2NaCl + H_2SO_4 = Na_2SO_4 + 2HCl.$$

The hydrochloric acid gas evolved is not allowed to escape, not only because alkali makers are legally compelled to condense 95 per cent. of it, and to allow no greater quantity to escape than 0·2 grain per cubic foot of air, but because of its value in the manufacture of bleaching powder. In this respect the salt-cake process has an advantage over the ammonia-soda process. The escaping hydrochloric acid gas is led up a pair of high towers in succession, and in these a stream of water descending through coke or brick absorbs the acid fumes, the dilute acid flowing out at the base. The salt-cake (sodium sulphate) is next heated (10 parts), with small coal (7½ parts), and limestone or chalk (10 parts), in a reverberatory furnace called the Balling Furnace. The reactions that take place in this furnace are represented by:—

$$Na_2SO_4 + 2C = Na_2S + 2CO_2$$
$$Na_2S + CaCO_3 = Na_2CO_3 + CaS.$$

In the first reaction the sulphate becomes changed into sodium sulphide, Na_2S; in the second the action of the chalk or limestone (= calcium carbonate, $CaCO_3$) results in the production of calcium sulphide, CaS, and the desired sodium carbonate, Na_2CO_3, the two forming a dark mass called "soda-ash," "black ash," or "ball soda." CaS being insoluble, the sodium carbonate is dissolved out in water, and after evaporating this, the carbonate is obtained. It is purified by again heating it with coal, and finally by crystallisation. The remaining calcium sulphide, once thrown away—hence the name "alkali waste" by which it is denoted—is a profitable source of sulphur production.

Carbon Cores.—Cores of small diameter but of considerable length made of hard compressed carbon. They are used in cases where ordinary sand cores would be liable to bend or

fracture by the pressure of the metal, unless supported by chaplets.

Carbon Dioxide, Carbonic acid, Carbonic anhydride, or Choke damp, CO_2, is produced by the combustion of fuel; by the process of fermentation; it is given off from subterranean sources and from the craters of volcanoes, and forms 4 to 5 per cent. of the expired breath of animals. It is present in the atmosphere (3 to 4 vols. in 10,000 vols. of air), and in natural waters, while in combination with other substances it forms many important carbonates. (*See* **Carbonate**.) It is easily obtained by the action of an acid on nearly any carbonate. Generally it is obtained by dilute hydrochloric, HCl, or sulphuric, H_2SO_4, acids on calcium carbonate, $CaCO_3$, in the form of chalk, limestone, marble, &c.

$$CaCO_3 + 2HCl = CaCl_2 + H_2O + CO_2$$
$$CaCO_3 + H_2SO_4 = CaSO_4 + H_2O + CO_2$$

In a less pure state it is given off from limekilns, the heat driving off CO_2 from $CaCO_3$ and leaving CaO, or quicklime, the monoxide of calcium.

CO_2 is colourless, with a faint smell, and slightly acid taste. It is very heavy, sp. gr. 1·529 (air = 1), and so accumulates in wells, pits, mines, and vats in breweries; it may thus be easily *poured* from one vessel to another. Carbon dioxide is liquefied under the pressure of 36 atmospheres at 0° Cent., then forming a colourless and very mobile liquid of sp. gr. ·947, boiling at − 80° Cent., and expanding rapidly as it is heated. On evaporation, liquid CO_2 becomes an extremely cold (− 78°), snow-like solid, raising blisters when pressed on the skin. If solid carbon dioxide is dissolved in ether, the solution quickly evaporates, lowering the temperature to − 100°. For this reason solid carbon dioxide is used for obtaining very low temperatures.

The poisonous action of CO_2 when respired is well known, its extreme effect being illustrated in the tragedy of the Black Hole of Calcutta. Miners dread it under the name of **Choke Damp**, while to its action and that of **Carbon Monoxide** are due the deaths of suicides in France who fill their chamber with fumes from charcoal stoves. Against this harmful effect on animal life must be set its constructive action in the vegetable world. In addition to its use in extinguishing fire, and as a refrigerant, in the manner referred to above, it is used commercially for aerating water. It is soluble in water, 1·79 vol. of CO_2 being absorbed by 1 vol. of water at 0°, and if pressure be applied (say 5 to 6 atmospheres), much greater quantities can be forced in. When the pressure is relieved as in uncorking lemonade, soda water, &c., the gas escapes with effervescence. The effervescence of champagne and other sparkling wines is explained in the same way, only in this case the CO_2 is formed naturally by fermentation.

CO_2 fills a large place in metallurgical processes, in the blast furnace, in the furnaces of steam boilers, in cementation, in cold storage. Hence constant references to its functions, reactions, and utilities will be found in every volume in this work.

Carbonic Acid.—*See* **Carbon Dioxide.**

Carbonic Oxide.—*See* **Carbon Monoxide.**

Carboniferous System.—It is not too much to say that the foundation of England's greatness, and her predominance as an industrial nation, were laid in the beds of the carboniferous system, for it is to the strata of this system that we are indebted for our coal supplies, as well as iron ores and many metallic minerals.

This system overlies the Devonian and Old Red Sandstone, and is immediately below the Permian. Its strata, as existing in England and Wales, are grouped as follows, working downwards:—

1. Coal measures	- -	about 10,000 feet.
2. Millstone grit	- -	„ 1,000 „
3. Carboniferous limestone		„ 15,000 „

The carboniferous limestone consists of corals, shells, and foraminifera, and is evidently of marine origin. The millstone grit comprises sandstones and shells. The coal measures, of fresh-water origin, are made up of groups of clay, coal, shale, and sandstone. The clay formed the soil in which the rank vegetation grew; the coal itself is derived from this primeval vegetation, which consisted largely of huge ferns, conifers, and lycopods; the shale was

deposited perhaps by great floods; and sand drifts account for the sandstones. As to the life then existent, the traces of land fauna tell us of huge amphibians and reptiles, land snails, scorpions, and extinct forms of such insects as cockroaches, locusts, and crickets. Fishes abounded in the sea, chiefly sharks and ganoids, the former preying upon the latter as evidenced by examination of coprolites. In the limestone we have evidence of an appalling wealth of marine life—foraminifera, corals, crustaceans, mollusca, polyzoa.

To the strata of this system we are indebted for our supplies of coal, for the ores of iron, zinc, and lead; for fire-clays; for sandstones which, according to hardness and durability, may be utilised as building stone, flagstones, grindstones, millstones, &c.; for the limestones used in the preparation of quicklime, mortar, and cement; and for the valuable bituminous shales.

Carbonist.—*See* **Allotropy.**

Carbon Monoxide, or Carbonic oxide, CO, is produced when carbon is burnt in a limited supply of oxygen. Unlike the dioxide, it is not present in nature, but is frequently produced during combustion, when it may be seen burning with a pale blue flame, as for example at the top of a coke fire. Oxygen and carbon form CO_2 in the lower part of the grate, and this gas, rising through the interstices of the coke, becomes changed into CO either by losing a molecule of oxygen or gaining one of carbon. In either case it burns and immediately unites with oxygen to form CO_2. A mixture of air and CO is explosive. Carbon monoxide is also extremely poisonous, ·5 per cent. in the atmosphere proving fatal, and, as it is abundant in the burning of charcoal and coke in particular, good ventilation is required where these fuels are used. It is colourless, has a specific gravity of ·96, is hardly soluble in water, faintly odorous, and is liquefied at −190° C.

Because of its great affinity for oxygen it acts as a powerful reducing agent, and herein lies its chief interest in blast-furnace processes. CO also plays an important part in the production of producer gas, water gas, Mond gas, and Dowson gas. In each case air or steam, or both together, are passed through incandescent fuel, and oxygen combines with carbon forming CO. Of the constituents of the gases eventually formed by these processes, the percentage of CO amounts to 24·4 of Siemens' producer gas, 21·0 of Lencauchez producer gas, 25·07 of Dowson gas, and 11·0 of Mond gas.

Carborundum (SiC, sp. gr. 3·12).—This is an artificial product of extreme hardness, being only exceeded in that respect by the diamond. Its colour in the pure state is white, but the commercial product, owing to impurities, varies between blue, green, and black. Water, acids, and oil do not affect it. Carborundum is composed of carbon and silicon in equal atomic proportions, and by weight of thirty parts of carbon to seventy of silicon.

The manufacture is carried on in electric furnaces at Niagara Falls after the process invented by Mr E. G. Acheson. The raw materials comprise coke, sand, sawdust, and salt. The coke has to be broken into lumps of a suitable size to form what is called the "core," while some is also ground to powder to form the mixture for the furnaces. All these constituents are then mixed ready for use. The furnaces are of brick about 16 ft. long by 5 ft. wide, and the same in depth. The ends are about 2 ft. thick, and into them are built the carbon terminals. The side walls of the furnace are built up to about 4 ft. high, and the mixture is thrown in to rather more than half fill the interior. A trench is now formed of semicircular outline, and the core is introduced into this. The walls are now built up further, and mixture thrown in to about 8 ft. The current is then turned on at a pressure of 185 volts, this being gradually increased as necessary to overcome the resistance of the core, which is greater in the early stages of the process than later when a good heat is reached. About 1,000 HP. is absorbed continually. In half an hour or so, gases are given off from the furnace, and subsequently the tops subside. After about thirty-six hours the current is shut off, the side walls being then taken down when sufficiently cool, the mass of unchanged mixture is removed from the top and a crust of amorphous carborundum exposed; this is cut through with steel bars and removed from an inner crust. The latter is detached and the crystalline

carborundum revealed. The core is composed of pure carbon, and from this radiate the carborundum crystals to a distance of about 12 inches. One furnace produces about 7,000 lb. of carborundum.

The crystals are next ground up in a crusher, and then placed in dilute sulphuric acid to remove impurities; washing, drying, and grading complete the operations. The forms in which the material is made up include wheels of similar shapes to those of emery, &c., sticks, hones, slips, paper, &c.

Carborundum Fire Sand.—This is a form of amorphous carborundum employed for refractory purposes, such as the repairing of furnaces.

Carburetted Hydrogen.—A compound of carbon and hydrogen. Light carburetted hydrogen, CH_4, more commonly called Marsh Gas, and also Methane, Fire-damp, or Methyl Hydride, is given off in considerable quantities in coal mines, and is the source of explosions. The percentage of CH_4 in coal-gas varies between 32·3 (in Paris) and 43·1 (in Bonn). In London the average is 37·6. It also rises from the mud in stagnant pools and in marshy districts owing to the decay of vegetable matter. It becomes liquefied at $-165°$ C. CH_4 can be artificially prepared by heating sodium acetate, $NaC_2H_3O_2$, with caustic soda, NaHO:—

$$NaCH_3O_2 + NaHO = CH_4 + Na_2CO_3.$$

Heavy carburetted hydrogen, C_2H_4, also called Olefiant Gas, Ethene, Ethylene, Ethyl, and Etherine, is obtained by the dry distillation of wood, coal, or other organic substances, and hence is also present in coal-gas, its average percentage being about 4. Under great pressure it becomes a thin and mobile liquid at $-110°$ C., which boils at $-103°$ C. and freezes at $-169°$ C.

Carburettors or **Carburetters.**—Appliances for mixing an inflammable vapour with air. Carburettors are used, to a limited extent, for supplying a mixture of air and gas to blowpipes, &c., for brazing, and for lime-light lanterns, for the latter purpose being known as ether saturators. Their chief use is, however, in connection with internal combustion engines, particularly those using petroleum spirit as fuel. These spirit carburettors are of two classes; the vaporising, or surface type, and the atomising, or jet type. In the former, air is drawn through, or over the surface of, the spirit by the suction exerted by the engine. This causes a certain amount of the spirit to be vaporised and mixed with the air, thus forming a more or less explosive mixture. The amount of spirit vapour thus taken up depends on the dryness and temperature of the air, and on the specific gravity of the spirit. The mixture formed may be too rich for complete combustion, in which case it is diluted by admitting a further supply of air alone to the inlet valve of the engine. Surface carburettors have the disadvantage that the lighter constituents of the spirit are evaporated first, leaving a residue of greater specific gravity, which less easily vaporises, thus causing variations in the proportions of air and gas. Also to be efficient they require to be of fairly large size, and hence there is always a danger of the contents becoming ignited, with disastrous results. Even at temperatures considerably below 32° Fahr. a mixture of petroleum vapour and air (of the right proportions) is explosive.

Atomising carburettors depend for their action on the suction effect produced by the rapid passage of a column of air past a jet, in which the liquid to be atomised is maintained at a constant level by the agency of a valve, controlled by a float. For some years the use of this type of apparatus was restricted by the owners of Maybach's patent, in which the float feed and jet formed the main claims. This patent was successfully contested in 1901, on the ground of anticipation by Butler's patents of 1888 and 1889.

Once the principle was thus set free, jet carburettors came rapidly into use, until, at the present time, they have almost completely superseded the surface type. Almost all the large firms manufacturing petroleum spirit motors have their own design of carburettor, differing mainly in minor details; the principle remains the same in all. The chief disadvantage of this type is that unless the engine is constantly worked at about the same speed, the proportions of air and gas in the explosive mixture will vary. The suction effect at the jet varies as the square of the velocity of the air, hence the speed of the column of air passing

the jet must be as nearly constant as possible to insure a mixture of unvarying proportions. Many devices are employed to obtain this condition, the commonest method being to provide a spring-controlled valve adapted to open when the speed of the air through the atomising chamber rises beyond a certain value (determined by the strength of the spring used), and admit air as a diluent. At the best such a method is a makeshift, and although giving fair results in practice, greater fuel economy would be obtained by so arranging the air passage, past the jet, that greater area would be given as the speed of the air tended to increase. A speed of 100 feet per second for the air passing through the atomising chamber may be taken as giving good average results, but this varies considerably in the many different designs in use. Probably the best known atomising carburettor at the present time is the Longuemare. The efficiency of this compares very favourably with any on the market. In place of a single orifice at the jet, a number of fine holes are used, and this undoubtedly makes the mixture more perfect.

Owing to the rapid and continuous evaporation of the spirit, heat is abstracted from the metal surrounding the atomising chamber. To such an extent does this occur, that it is by no means unfrequent for the moisture in the atmosphere, condensed on the exterior of the apparatus, to be frozen. At low temperatures the spirit naturally does not vaporise so freely. Hence it is usual to compensate for the loss of temperature due to the evaporation by surrounding the atomising chamber with a jacket, through which either a portion of the hot exhaust gases, or the water heated by circulating through the cylinder jacket, flows. The water jacketing is preferable on account of the more equable temperature. If the mixture of air and gas be heated unduly, expansion takes place, with the result that the weight of the charge admitted to the engine cylinder is diminished, with a corresponding loss of efficiency in fuel consumption. Jet carburettors require to be nicely proportioned, as the correct mixture of air and gas, for complete combustion, can only be varied between narrow limits. With a mixture of 1 volume of liquid petroleum spirit to 10,000 volumes of air the mixture will not explode, or only very slowly. With 1 volume of liquid spirit to 6,000 volumes of air combustion will not be complete. The best average composition appears to be 1 volume of liquid spirit to 8,400 volumes of air, corresponding to about 2 per cent. of vapour. At 60° Fahr. dry air will not be saturated with petroleum spirit vapour until it has absorbed about 15 per cent. by volume.

The heavier hydrocarbons, such as paraffin, cannot be successfully vaporised with a surface type carburettor,—the atomising type must be employed. Unlike petroleum spirit, paraffin requires to be heated after atomising to form a mixture which will be completely consumed. When heat is applied to the petroleum oils, there is a critical temperature which must not be exceeded, or the oil will be "cracked," and a tar-like residue will be deposited in the pipes and valve ports. Variations in the speed of the engine using heavy hydrocarbon as fuel, generally cause trouble in the carburettor. Frequent adjustment of the mixture is necessary if the engine is required to run at different speeds. At the present time there is no carburettor for utilising paraffin with anything like the facility with which petroleum spirit is employed. Most of those in use have a jacket around the atomising chamber through which the heated exhaust gases are circulated, in order to supply the heat necessary to vaporise the oil. In some few cases an external flame is used to heat the vaporising chamber, and with this system the degree of heat is more under control. With the exhaust gas jacket the temperature is liable to variations, especially in the case of those engines in which the governing is effected by cutting out one, or more, explosions, when the speed increases beyond the limit decided on. This periodically lowers the temperature of the vaporising chamber, sometimes to such an extent that the oil will not vaporise at all, thus causing the engine to stop.

Carburising Furnace.—The term might be legitimately applied to a furnace in which blister steel is produced, or work case-hardened, but these have their own specific names. It is

applied properly to a furnace in which the surface hardness is imparted to armour plates.

Furnaces used for the purpose at the works of Vickers, Sons, & Maxim, Ltd., Sheffield, are constructed as follows:—

They are 36 feet long and 21 feet wide, to take the largest plates. The outer walls are of brick-work, cased with steel plates, supported by rolled joists, and braced by steel bolts. There are four regenerator chambers below for gas and air supply, fitted with valves. The armour plates, laid in pairs, are carried on a car built of rolled H beams, covered with a 9-inch thickness of fire-brick work. The sides of the car have channel irons filled with sand. Channel plates built in the side walls of the furnace engage with the channels on the car sides, to prevent leakage of cold air in the furnace.

The car is carried on ten wheels with roller bearings to the axles, and these being below the bottom of the furnace are not subjected to heat. On the brick-work of the top of the car a series of flues is constructed extending to the full length of the car for the passage of the hot gases, and over these the armour plates are laid, two in number, face to face, with their faces covered with powdered charcoal. The two are therefore carburised simultaneously. A covering of ordinary sand is laid over and around the plates. Sheer legs load the car, and various agencies run it in, as a steam engine, electric motor, or locomotive, and the door is closed and made air-tight.

The hot gases enter at the back, the flames pass over the top, and down at the front through the flues underneath the plates, and thence through exits which abut against the flues on the car, and so to the chimney.

The essential feature is that as the charcoal lying between the plates can only be heated through the flues in the brick-work, and through the overlying sand, the plates must fully absorb the carbon from the charcoal. This alone would not harden the plates apart from subsequent sprinkling with water, which is done after the bending and machining.

Car Coupler.—*See* **Coupler.**

Card System.—A method of indexing or recording facts, figures, or information of any kind. For engineering establishments, it is invaluable in the clerical departments. The basis idea is the use of removable cards or leaves, as compared with the use of bound up or fixed leaves in a complete book; in other words, it is the adoption of an indefinitely expansive unit instead of a non-expansive fixed quantity. The net result is a great saving in time, labour, and material. Used first as an elastic index for libraries, it has come into universal employment in everyday business life, not only as an index, but in the slightly disguised form of "loose leaf," or "perpetual" book.

The application of a card index to the correspondence department shows it to be a tremendous time saver. The usual method of filing correspondence has been to "press-copy" all outgoing letters in a book, and to record all incoming letters in alphabetically arranged files or pigeon holes. When the correspondence with any customer has to be gone through in order to ascertain certain facts, it is necessary to assemble a collection of loose letters from various files, together with several copy books, and then to wade through a considerable number of references in order to establish a continuous correspondence, during which time other members of the staff are waiting for the same books to deal with other customers' letters. It is now usual to keep a separate folder or cover for each customer, and to place or secure therein every letter received, together with a copy of reply, in chronological order. Thus one has a continuous book, giving a complete record of correspondence.

These books may be kept in drawers in alphabetical order, but in practice it is more convenient to number each one separately, keep them in order of number, and to instal an index. Each customer or correspondent has his name and address written on a card, and a number is assigned him, Fig. 115, A. This number is written on the card and on the folder. The cards are assembled in a suitable drawer or drawers in alphabetical order, and at intervals blank cards are inserted, having projecting portions or "tabs" upon which are written guiding letters or names according to the extent or bulk of the firm's correspondence. Thus, to find a

particular folder it is only necessary to look up the correspondent's name upon a card behind the tab card which bears the initial letter of his name. Say the number on his card is 0632, then that number folder is picked out of the folder cabinet and the complete correspondence with him is at once to hand, both letters and answers being in the order in which they were written.

The card and the folder are thus expansive units, always complete, yet always capable of extension without interfering with order. New customers have cards and folders assigned them, and these find their places alphabetically and numerically without upsetting previous work. The card drawers and the folder cabinets are constructed in units and are also expansive.

There are many advantages in using the card

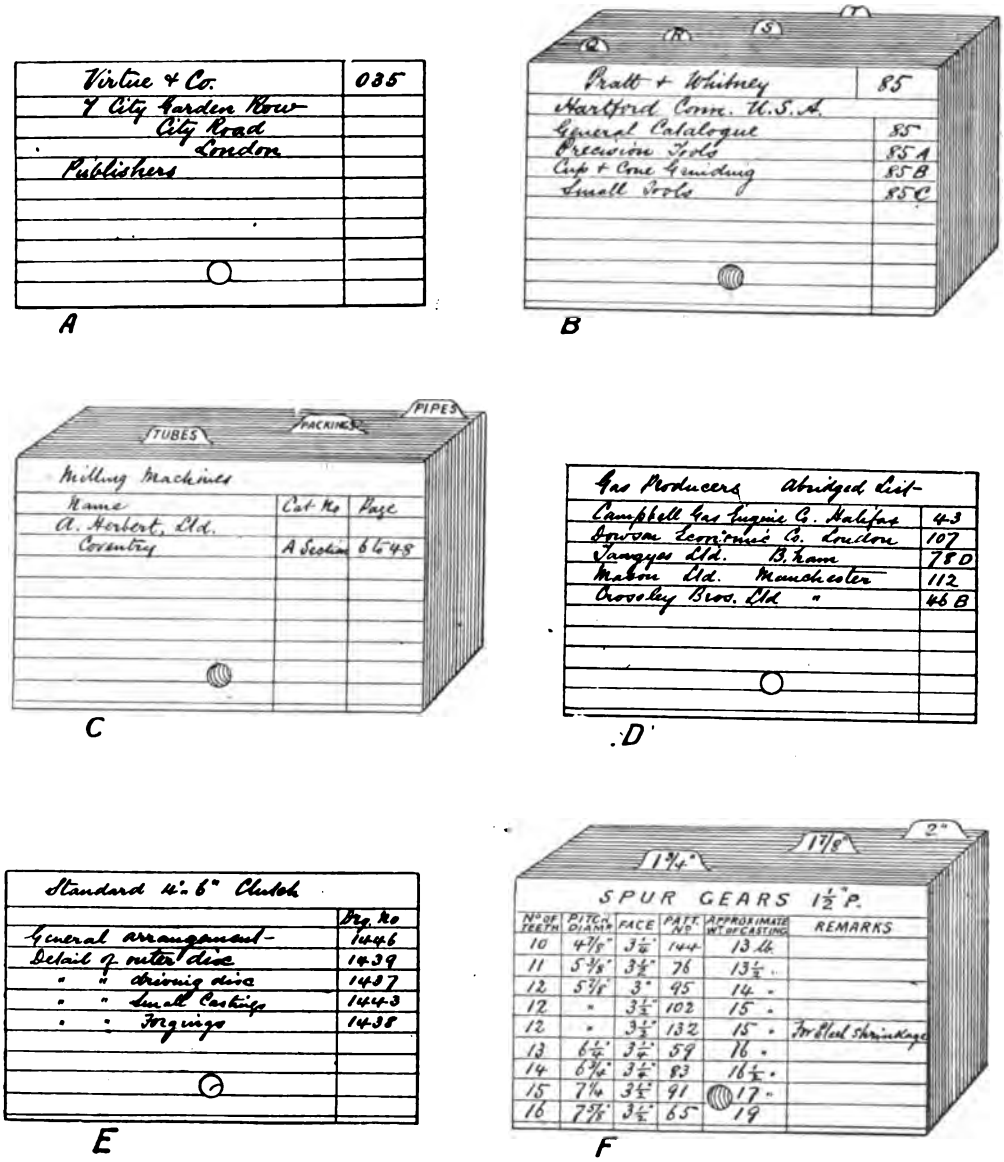


Fig. 115.—Card Indexing.

index which can only be realised by actual experience; for example: cross references, coloured guide cards, geographical divisions, for correspondence with agents and travellers. An idea to be grasped is that a folder may be indexed in many ways, but is to be found in only one place; this idea is perhaps most clearly seen by the application of the card system to catalogue filing.

A good catalogue register is a necessity for an up-to-date firm, both as an assistance in estimating, and purchasing, and as a means of knowing what competitive houses are doing; a register in ordinary book form soon becomes a nuisance when allotted spaces are filled up and references have to be made to other pages. With a card system, each firm represented by a catalogue or catalogues has a separate card assigned to it, and a number is written on the catalogue and on the card. The catalogues are kept on shelves like ordinary books and in numerical order, the cards are kept in proper drawers in alphabetical order, with lettered guides, Fig. 115, B, as for the correspondence system. When a particular firm's catalogue is required the name is looked up on the card index, and the number found. But it is not always convenient to pick out a desired article or machine from the remembrance of the manufacturer's name, therefore a second drawer of cards is formed in alphabetical order, dealing with the subject-matter of the catalogues, the guide cards bearing the name of the machine which is registered on the cards behind it, Fig. 115, C, D. Thus if particulars of a gear cutting machine are required it is only necessary to look behind the guide card which is marked "gear cutting machines," and an alphabetically arranged set of cards each bearing the name of a manufacturer will be found. The catalogue number is on the card, together with the page or pages of the catalogue dealing with gear cutting machines. Thus it will be seen that although the catalogue has only one number, and one place, it may be found by two or more distinct methods.

Again, catalogues may be registered geographically, either by having a third drawer of cards, or by using coloured cards to represent either counties or nationalities; so Yorkshire tools or makers may have yellow cards, Glasgow blue, American red, German buff, French silurian, &c., &c. If an American machine is being sought for, one picks out the red cards only, and so forth.

The card index is a great time saver in the drawing office; as each and every drawing is made, it is numbered and stored in that order in drawers, the outside of the drawer bearing a ticket which shows the inclusive numbers stored therein. Each machine or line of machines manufactured has a card allotted to it, upon which is written a complete list of drawings relating to it, together with the drawing numbers, Fig. 115, E. The cards are then assembled in a drawer, and suitable guide cards are inserted to divide them into convenient groups. For instance, all cards relating to planing machines would be assembled behind a guide card marked "planing machines," all cards relating to milling machines would find their place behind a guide marked "milling machines." Subdivision tabs may be inserted to locate standard or special machines, or alternatively, all standard machines may be listed on particular coloured cards. The expansive quality of the card system is here again seen clearly: any fresh or special machine finds its place numerically in the drawings, and alphabetically in the cards, without waste of space, or paper, or disturbance of previous records, and also by this method any drawing relating to older machines may be used and referred to without duplication or intermingling of groups or portfolios.

A card index is a great boon when applied to pattern registers, both in shop and office; wheels, and standard elements can be grouped on cards behind suitable guide cards, Fig. 115, F, in such a way as to be at once accessible from different points of search.

Again for timekeeping, time charging, costing, pay sheets, stock lists, &c., &c., the card system is a very material help in assembling facts and figures in a convenient and get-at-able form. The subject is a wide and interesting one, and although it is possible to ride it to excess, and to red tapeism, it is indisputable that its rational application is absolutely indispensable to any firm that would be in the van of progress.

The card system in the shops lessens the work of foremen and clerks by the practice of

printing the cards in distinctive colours for the different departments, and also for piece work, and day work, besides other distinctions, so that a glance suffices for the sorting out of cards according to shops or subjects.

As cards are filed from day to day, according to their order numbers, it is far easier to check the cost of a job during its progress than it is when entries have to be made in office books, and posted up after the job is completed.

The card system is a check upon the management of shops, since it reveals any neglect on the part of shop managers and foremen to keep men fully employed. In a busy shop, where a foreman's hands are full, it is really very difficult to keep every man occupied without any idle intervals occurring. It is especially so in general and repair shops. Within the course of a single week men may be overdriven, and be slack. This is due partly to fluctuations in the volume of work, but quite as much to the difficulty of apportioning the various jobs suitably among suitable men.

But after allowances are made, there is in certain shops a good deal of wasted time between finishing one job and starting on another. Time cards will check this leakage.

A finer division of tasks is rendered possible by card systems than by the usual method of charging time. Each detail of work, however petty it would seem in the general shop, is located on the cards. In this way it becomes possible to ascertain the exact cost of every separate detail.

The costs of a given piece of work done by different men can be quickly seen by a comparison of cards, the differences between both workmen and methods can be noted at a glance, and basis prices can be extracted for future guidance.

Carnot's Principle.—Carnot showed in 1824 that heat only performed work when let down from a higher to a lower temperature, though he was unaware that any of the heat disappeared. The cycle of operations in an ideal steam engine was first examined by Carnot.

The Carnot cycle supposes the working fluid —a perfect gas—contained in a cylinder at a temperature T_1. To this cylinder is applied an infinite source of heat also at a temperature T_1, which keeps the expanding gas at the uniform temperature, *i.e.*, expansion is isothermal. The hot body is then removed, and the gas expands adiabatically. The original pressure, volume and temperature being P_a, V_a, and T_1, become P_b, V_b, T_1 at the end of the isothermal expansion, and P_c, V_c and T_2 at the end of the adiabatic expansion. Then a force being applied to the piston, the gas having done work is isothermally compressed to P_d, V_d, and T_2 with the cylinder cooled by contact with a cold body at a temperature T_2. Then the cold body being removed, compression is applied adiabatically until the gas attains the original pressure P_a, volume V_a, and temperature T_1. This completes the closed cycle, and it can be shown that in order that the cycle shall close, the rate of isothermal compression in the third stage must be equal to the initial stage of isothermal expansion, for $\frac{T_1}{T_2} = \left(\frac{V_c}{V_b}\right)^{\gamma - 1}$, where γ = the number 1·404 for a perfect gas, or very nearly so, is the cooling effect in stage (2); and the heating effect in stage (4) is,

$$\frac{T_1}{T_2} = \left(\frac{V_d}{V_a}\right)^{\gamma - 1}, \text{ whence } \frac{V_c}{V_b} = \frac{V_d}{V_a} \text{ and } \frac{V_c}{V_d} = \frac{V_b}{V_a}$$

The heat taken in during stage (1) is $CT_1 \log'. \epsilon r$; during stage (2) there is no gain or loss of heat except by conversion to work. The heat rejected during stage (3) is $CT_2 \log'. \epsilon r$, and again there is no change during stage (4) where $C = 53{\cdot}18$ for P in lb. per square inch, V = volume of 1 lb. in cubic feet, and T = absolute temperature in Fahrenheit degrees.

For air, $PV = 53{\cdot}18T = CT$.

Then the efficiency of the Carnot cycle or heat converted into work ÷ heat taken in is,

$$\frac{C\,(T_1 - T_2)\,\log'. \epsilon r}{CT_1 \log. \epsilon r} = \frac{T_1 - T_2}{T_1}$$

This is the maximum possible efficiency of the ideal steam engine, being the measure of perfect efficiency on which practical efficiencies are compared. The perfect engine is reversible as to its cycle, or it can be driven round by an external force, and the work converted into heat and *vice versa* in the reversed order (4) (3) (2) (1) of the stages described, and the supposed sources of heat and of "cold" would

now gain and lose heat respectively where they lost and gained on the heat into work cycle.

Carpentry.—In engineers' work carpentry does not occupy so important a place as formerly, but for many purposes timber is still either invariably employed, or it is retained as a good alternative to metal, to masonry, and to concrete. In the Colonies it is used much more extensively than in England. Engineers' carpentry, as distinguished from joinery done in railway shops, is usually of a large and heavy class, in which balks, or whole timbers, are mostly necessary. The methods of jointing and fastening adopted in general joinery are therefore as a rule neither suitable, nor substantial enough. The mortise and tenon fitting is most commonly adopted. Bolts, straps, and tie rods are used, and castings are frequently made to receive the ends of timbers, to connect them with other parts of a structure. A considerable amount of engineering carpentry is for work of a temporary character, such as centering, staging, cofferdams, and piles, used during excavations, and in building operations. In permanent work timber is employed in the piles and structural work of some piers and bridges, for factory roofs, for the gantries of travellers and cranes, and frames of trucks, and for many other purposes. In some cases, as in piles, the work to be done is of a rough character; while in others, as in framed work of various kinds, the joints have to be selected with judgment, and accurately fitted, so that they will not be affected by the shrinkage of the wood. Closely fitting joints are as essential in heavy woodwork as in small, as for example in centerings, and in cofferdams.

Timbers.—The timbers used in heavy carpentry are chiefly the deals. "Deal" is the term commonly used to signify the softwoods of the natural order Coniferæ, known as fir, spruce, pine, with various distinguishing adjectives which are necessary owing to the differences in character of similar woods grown in different localities, as red, yellow, Riga, Memel, Dantzig, pitch pine, &c. These woods are imported from North Europe, Canada, and the United States. They are all of low specific gravity, and light in colour; straight-grained, and of large size, especially in length; comparatively soft, and consequently easier to work than hardwoods, while for many purposes they are practically as strong and durable. Kauri pine, a large New Zealand wood, is useful in constructional work.

Oak is the hardwood most commonly used. Formerly, in England, it was employed almost exclusively for heavy timbering, but the importation of cheap softwoods, and the great diminution of the native supply of oak has relegated it to a second place, and the oak timber used now is chiefly imported. It is considered superior to softwood, but its cost, greater weight, and the extra trouble of working, restrict the use of oak to purposes where quality is so essential that they can be disregarded.

The hardwood next in importance to oak is elm, valuable because of its resisting power to moisture. Piles of elm are extremely durable. Ash is used for purposes where flexibility and resistance to shocks are required. Indeed, in the case of all hardwoods each is singled out according to its characteristics, for purposes where those characteristics are desirable in the material.

Among hard timbers, the jarrah has a high reputation for durability in exposed situations and under water, while its large size, 40 ft. to 80 ft. in the stem, and from 2 ft. to 8 ft. in diameter, renders it of great value. Karri is larger and stronger, but not so durable in damp situations, though it stands well under water. The red gum is another valuable timber, as large as jarrah, and stronger and tougher. Iron bark is about the hardest and strongest of timbers, and makes good piles. Blue gum is largely employed in engineering works, but it is not suitable for piles. Greenheart is largely used, but mostly in internal work, and for submerged work. Teak is used in ship's joinery. Apple wood, beech, hornbeam, acacia, are all used by engineers for cog wheel teeth and other purposes.

The hardwoods are so numerous and so different in character that each has its special purposes, and few are equally suitable for all classes of work. None have such a large and varied field of utility as the varieties of softwood. The timbers now in use are much larger in number than those of half a century ago, owing to the spread of commerce and the

importation of foreign woods which were scarcely known a few years since.

Timber always has to undergo a process of seasoning or drying before being used. It is not possible to thoroughly season entire trunks or balks, nor is it so necessary as in the case of wood used for indoor purposes. Unless artificially seasoned, carpenter's timber is not considered fit for use until at least two years after the tree has been felled. During that period the sap gradually evaporates, and the wood shrinks, and can then be relied on not to cause trouble through further shrinking when worked up into a structure.

For some purposes, as when subjected to alternate wetness and dryness, the decay of timber is delayed by artificial means. The process which is generally adopted is that of **Creosoting**, which consists simply in injecting oil of tar or creosote under great pressure into the pores of the seasoned wood. This makes it poisonous to insects and all the forms of parasitic life that cause decay in timber. There are other fluids injected in timber which is to be subjected to conditions that induce decay, such as contact with the ground, or alternate wetness and dryness, as in railway sleepers.

Owing to the great differences in the range of quality in various specimens, it is impossible to calculate the strength of timber structures with the close approximation practicable in metal work, and consequently a high factor of safety is always allowed.

Timber is also subject to a number of defects that seriously impair its strength. A piece in which large shakes or cracks occur will easily split in the line of the cracks. A piece with knots has the continuity of its grain broken and its strength diminished. A cross-grained piece of timber is a great deal weaker transversely than a straight-grained piece. Timber may have other defects that are more in the nature of diseases, but those mentioned are the ones commonly met with, and to a more or less extent they are nearly always present in all timber. Cracks, or shakes, as they are more commonly called in the shops, usually occur during seasoning. They are caused by the outside of the wood drying and shrinking faster than the inside. Practically it is impossible to entirely prevent them. Knots are commoner in some woods than in others. In spruce they are always very plentiful. They represent the places where branches have grown from the trunk. Knots do not seriously reduce the strength of a piece of timber unless it is cut to so small a section that the knots occupy a large proportion of that section, to the displacement of the regular fibres on which the wood depends for its strength. But owing to their hardness compared with the surrounding fibres, knots are objectionable when the wood has to be operated on with cutting tools.

Methods of Union.—Speaking generally the union of parts in engineering structures is not

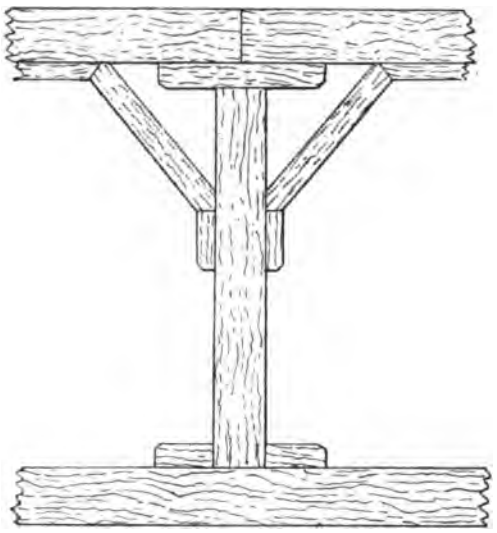


Fig. 116.—Example of Abutting Joints.

accomplished by the fastenings effected by timber joints, but by extraneous assistance. Such joints as are made are rather for the purpose of preventing slip between adjacent parts; their security is provided for otherwise. Thus, the dovetail finds little utility. The tenon, and its cousin-german the joggle, are largely used, but glue being out of the question, the fish plate, strap, or tie, secure the parts. There is also, as already mentioned, a large group of work in which castings form the elements of union, and they are generally utilised for other functions, as for tie-rod attachments.

Castings in engineers' carpentry may be classed under two heads; those which are em-

ployed as bonds of union, and those which are not. To the first group belong roof shoes, the castings at top and bottom of timber jibs, those for the masts of derrick cranes, and those for timber sheer legs. In the second are included the bearing castings which go on timber masts and jibs, for the ends of traveller gantries, and for the struts of the same, dead-eye bearings on timber-framed work in general carrying shafts and gears. In all such work means must be taken to ensure absence of all risk of slip between the castings and the timber. Socketed castings require nothing beside, since the timber

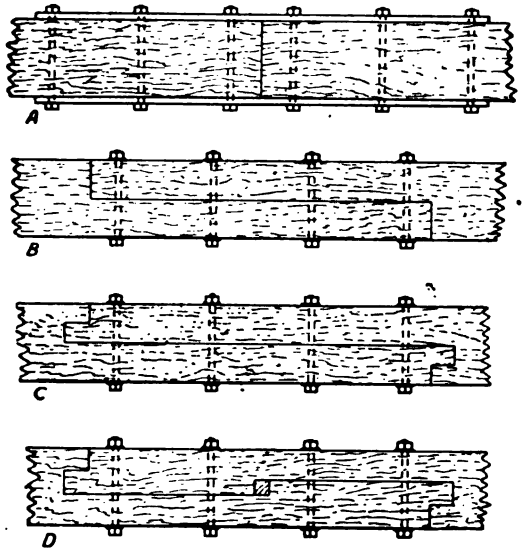


Fig. 117.—Joints in Balks.

ends are driven in. Castings on timber faces must have side flanges or else joggles. The latter involve cutting away a little of the timber; the former do not.

The joints in heavy timbering are almost invariably held by bolts or tie rods. The simplest form of joint is a butt joint, Fig. 116, in which one member abuts against another, and the two are held together by through bolts, often in conjunction with straps or fish plates, Fig. 117, A. Although it rather limits the meaning of the term, a butt joint is generally understood to mean one in which the end of one member abuts against either the end or side of another. When two ends meet in this way fish plates are usually employed to hold the members together in line and stiffen the joint, but in most cases the strength of the joint is increased by making it a scarf instead of a butt joint. In a scarf, or scarfed, joint the fish plates are often retained, but the ends of the timber are cut so

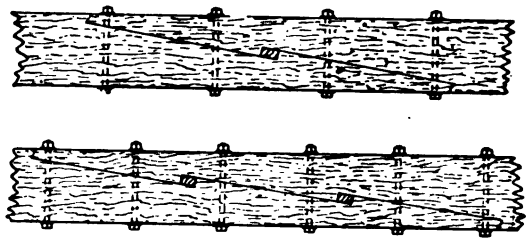


Fig. 118.—Scarfed Joints in Balks.

that they overlap each other for some distance, while still allowing the members to be in the same plane with each other. Scarf joints vary in form, from a plain half lap to intricate joints following different angles, with slots cut to receive keys for wedging, Fig. 117, B, C, D, and Fig. 118. By these methods, end joints can be made practically as strong as if the timber was a solid length; and moreover, when a timber is required of such a length that joints are necessary, it is usually so well supported at various points in its length that the strain on the joints amounts to very little.

Balks occasionally are joined side by side when a timber of very large section is required.

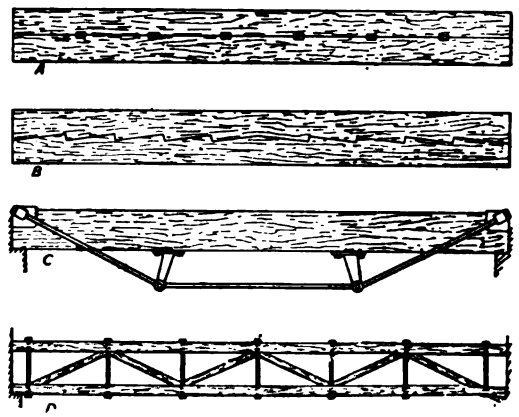


Fig. 119.—Jointing of Balks and Strutting.

In such cases the joint is often made with steps or joggles in its surface instead of plain, Fig. 119, A, B. When great transverse strength is required, a metal plate of the same length and width as the beam is inserted between the

halves. This is sometimes done in preference to using a beam of solid wood, the beam being first sawn down, and then bolted together again with the plate between, the heart faces of the two halves being then turned outwards. This is called a *flitched beam.* Fig. 119, C and D, illustrates trussed beams.

When pieces meet at right angles we have the choice of a butt joint held by straps or bolts, and sometimes assisted by wood blocks on either side; or a mortise and tenon joint in which a tenon on the end of one piece fits into a mortise cut in the surface of the other, and secured with bolts, Fig. 120. The method and details depend on circumstances. In members which meet diagonally the same methods are applicable, modified to suit the case. We have also the half lap, or halved joint, in which the

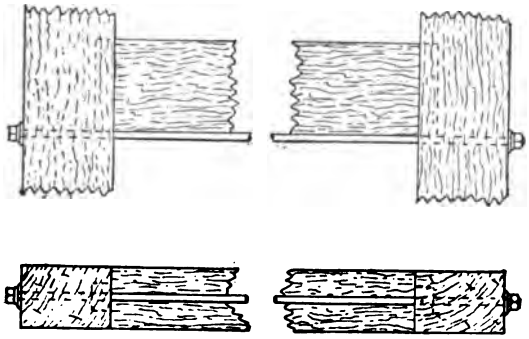


Fig. 120.—Stump-tenoned Joint with Bolt.

pieces lap sideways, half the thickness of each being cut away to permit them to lie flush. In heavy carpentry this method is seldom employed, because it weakens the timbers to cut so much away. There are also a great many joints, especially those which meet at angles, in which the timbers enter into castings specially made to fit them.

Machinery is used now for all operations where it can be economically employed. There is vastly less hand sawing and planing than was formerly the case; and where work of the same character is repeatedly wanted, machines are employed to do it. Mortises and tenons are cut, holes are bored, rebates and grooves are sawn or planed, turning is done automatically, pieces are sawn, planed, or cut to size by machines; and machinery is employed to a great extent for the more convenient handling of material. In heavy carpentry the use of machinery may be seen to its greatest extent in such work as the construction of the underframes for railway rolling stock. Here the work is of so repetitive a character, and done on so large a scale, that machines can be used advantageously for everything.

See also **Caisson, Cofferdam, Creosoting, Crib Work, Piles, Sheet Piling, Timber Seasoning,** and woodworking machinery, under various headings.

Car Pusher.—A motor used for moving ingot mould cars while casting. It may be described as a low stiffly-built electric locomotive. The motor drive is geared down to the leading wheels, which run on rails, and the axles of which are fitted in axle boxes with stiff coiled springs. The Wellman car is 11 ft. 6 in. over all, is to standard 4 ft. 8½ in. gauge, and stands only 4 ft. 5½ in. at the highest part.

Carrier.—This appliance, also termed a "dog," and used for attachment to rotating work between centres in lathe and milling machine, is made in diverse forms. The commonest type, the heart, Fig. 121, A, B, takes a rather limited range of sizes in the aperture. (The screw may have a swivel piece, as shown, to bear on work.) The driving is done by the pin held in the driver plate of the headstock. An alternative to this plan, the bent-tail carrier C, D, dispenses with the separate driver pin, and keeps the carrier from rattling, in the case of work that is rough, or has gaps on the body, so that the tool does not cut continuously. The type A in such instances falls away from the driver, and fetches up against it when the cut comes on. The heart carrier is also made with double arms E, securing equal balance and drive on both sides of the centre, a driver pin pressing on each arm.

A type of carrier which is useful for heavy driving is shown at F, comprising two vee plates clamped on the work by the bolts, which enable a powerful grip to be obtained. The plates need not be thick, as would be essential if screws were tapped in. Either a single or a double driver may be used with this carrier. Flat plates are also employed for squared or flattened work where the heart carrier is of no use. When set-screws are employed instead of through bolts, the plates must be thick to insure durability of the threads, as at G. This is

a type favoured for small work. A pin is often fitted into (or forged on) one clamp. A modified form for larger sizes has stronger clamps forged of ample depth to resist bending, H. For gripping tapered pieces, a variation of this design has the screws pivoted on studs at the ends of one clamp, so that the latter may swivel to accommodate the slope J. Another design for tapered work, shown at K, consists of a right-angled clamp, made of thin strip steel, bent double with a space between, so that the holding piece, screwed at each end, may pass through and receive nuts. These are convex-faced, resting on concave washers, so that freedom of movement is allowed for. A type which does not depend on a screw for holding, utilises the pressure of the driver pin for forcing the serrated jaw of the arm against the work, and compelling it to revolve.

It is occasionally necessary to drive a screwed piece, and then, to avoid damage to the threads, a split carrier should be employed—screwed inside to fit the work, and tightened on the same by a set-screw drawing the split lug together, L, so driving the work by friction. Sometimes a carrier is dispensed with altogether by the expedient of screwing or driving a pin into the work, M, though this is not practised except for pieces such as mandrels in permanent use. N is a carrier for putting on work held between index centres in the milling machine, instead of the ordinary bent-tail dog, O. When doing angular cutting (as on bevels), the tail waggles about awkwardly in the driver slot; cranking simply as at N and P obviates this. The dog is lettered *a* in O and P.

Cartridge-Case Making.—This special branch of sheet-metal working is notable for the remarkable amount of extension or drawing which is done upon the metal. The number of operations vary according to size, but Fig. 122 represents a typical series for a 3-pounder quick-firing type. The processes are:—A, blank; B, cupping; C, D, E, first, second, and third drawing; F, first indenting; G, fourth drawing; H, second indenting; J, K, fifth and sixth drawing; L, cutting to length; M, heading; N and O, first and second tapering; P, turning head; Q, cutting to length; R, boring and tapping primer hole. Sectional views of some of the dies are seen in Fig. 123, lettered similarly. Blanking is done with an ordinary punch and die; cupping by forcing the blank through a die which decreases in diameter;

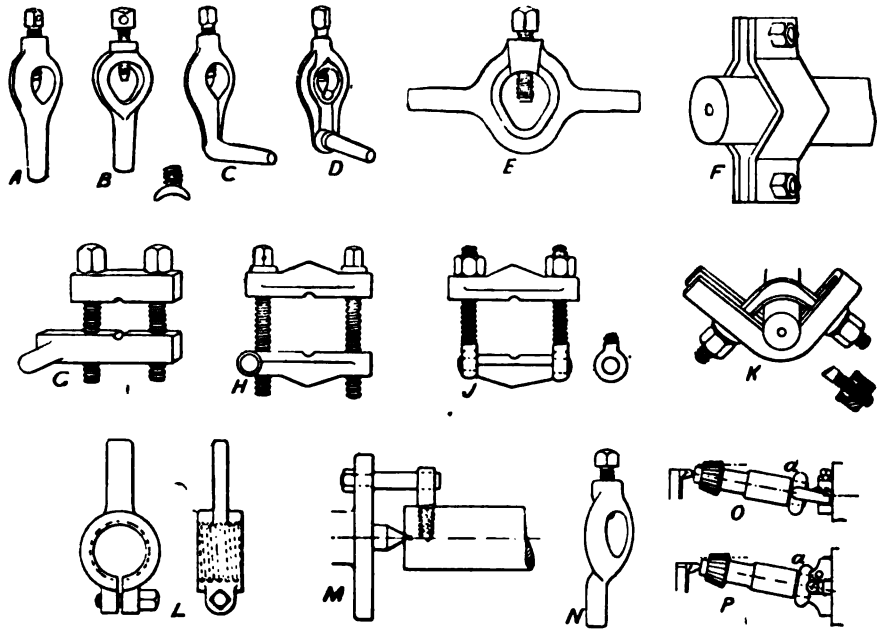


Fig. 121.—Forms of Carriers.

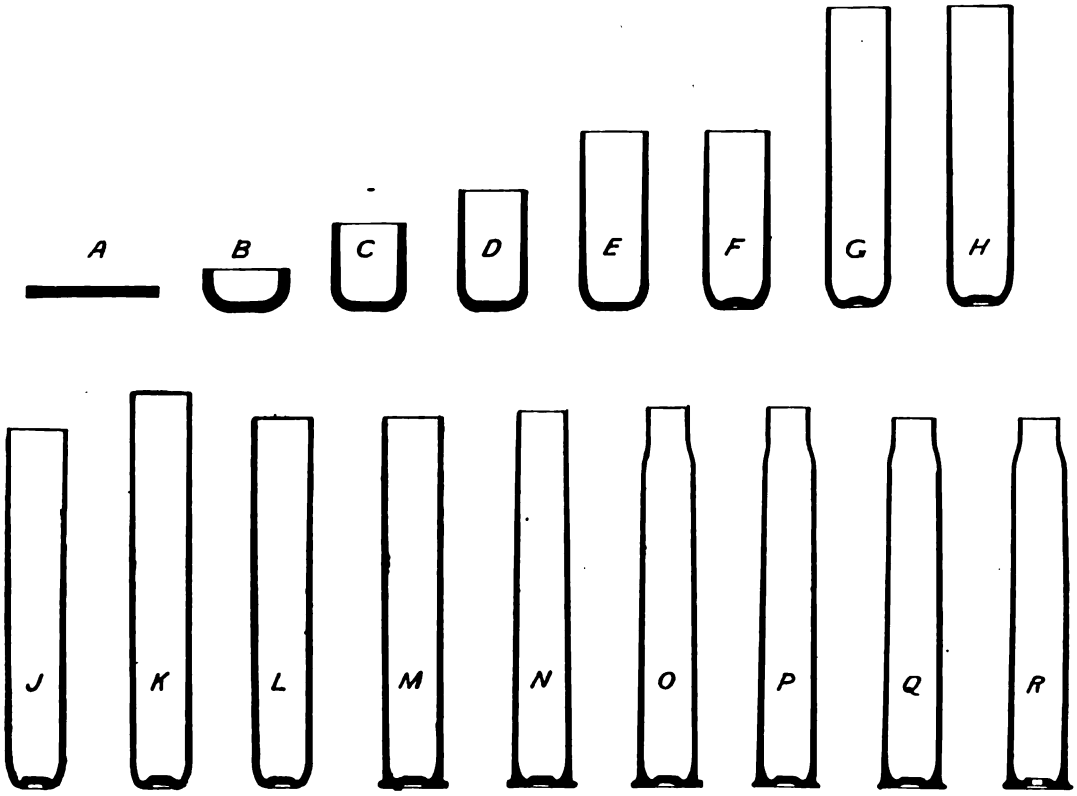


Fig. 122.—Operations in Cartridge-Case Making.

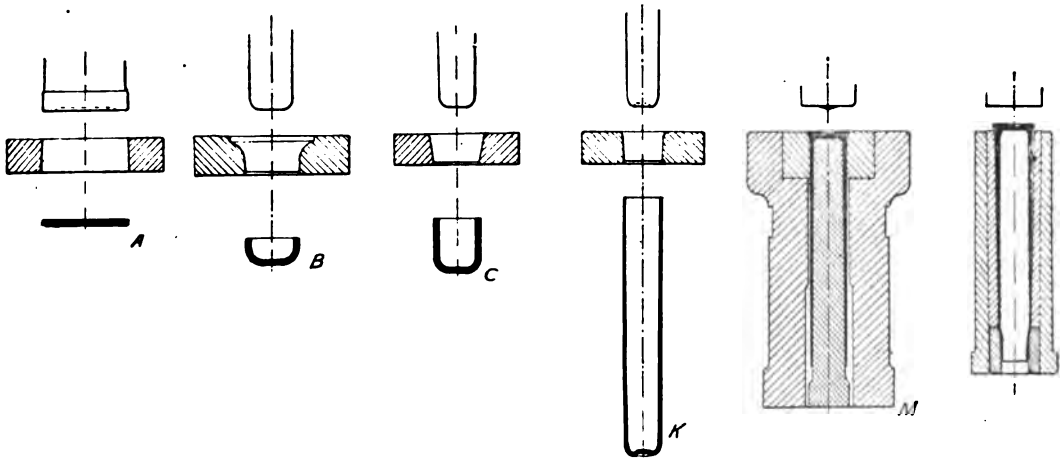


Fig. 123.—Dies used in Cartridge-Case Making. (James Archdale & Co., Ltd.)

first drawing by passing through another die, having less taper, as the cup is easily inserted; the subsequent drawings, ending in the sixth, result in great extension. The heading is done with the cartridge turned upside down, upon a mandrel; and the tapering by forcing it into a tapered die. A power-driven machine by Messrs James Archdale & Co., Ltd., in which these operations are effected, is seen in Fig. 124, comprising a framing carrying a vertical ram reciprocated by gear wheels and crank shaft, and a table having a rotating dial with a number of holes, in turret style, the use of which is to bring the cupped cases over the die in succession, the ram then descending and forcing the drawing punch through. The object of the turret device is to facilitate rapid production, the operator having simply to keep the holes filled as they come around, instead of waiting for the rise of the ram to slip in a piece, which is a slow method. The table is rotated automatically. The different dies are slipped under the plate and located with the taper pin seen.

In the case of heavy cartridges, hydraulic drawing presses are often employed. The alloy most commonly used is a brass composed of two parts copper to one of zinc. Slight variations are made by different people. Annealing is a very necessary treatment between the operations, because the drawings impart hardness and brittleness to the metal, which is got rid of by heating and cooling.

Car-Wheel Boring.—This operation is most economically performed upon what may be classed as a vertical chucking machine, Fig. 125, Plate IX. The wheel is gripped in the jaws of the rotating table, and the hole is bored by the vertical bar, fed downwards, the hub or boss being faced also by a tool held in the side ram, projecting from the machine framing. A special feature is the jib crane, seen at the side, the chain being hoisted by a small drum, actuated by worm gear from a belt pulley, which enables the wheels to be hoisted on to and off the table very rapidly.

Case Hardening.—This is the opposite of annealing. The surface of a soft malleable forging of iron or mild steel is rendered hard as steel by the addition of carbon at a high temperature. In annealing, a hard casting containing a considerable amount of carbon is softened by the abstraction of a portion, or the whole of the carbon, or by the conversion of combined carbon into graphite. The presence of a cementing material, and of heat are essential in both, as is also the exclusion of air. The period necessary for treatment varies with the degree to which either process has to be carried, and with the mass of the work.

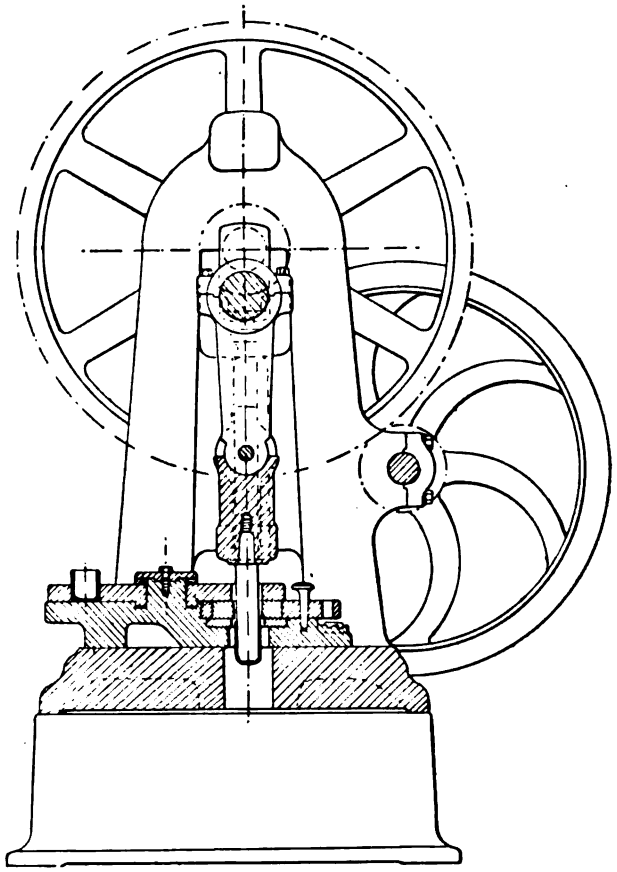


Fig. 124.—Drawing Machine, used in Cartridge-Case Making. (Jas. Archdale & Co., Ltd.)

Case hardening has analogies to the produc-

tion of blister steel. *See* **Cementation**. But the process is very much shorter, and animal charcoal is used instead of vegetable. In each case the steely product is of a more or less spongy character, and for this reason case hardening should not be carried to a greater depth than is necessary for durability.

Case hardening covers a multitude of processes for the production of various results. In general, durability of wearing surfaces is the object sought, the most familiar example of which occurs in motion work. But variegated

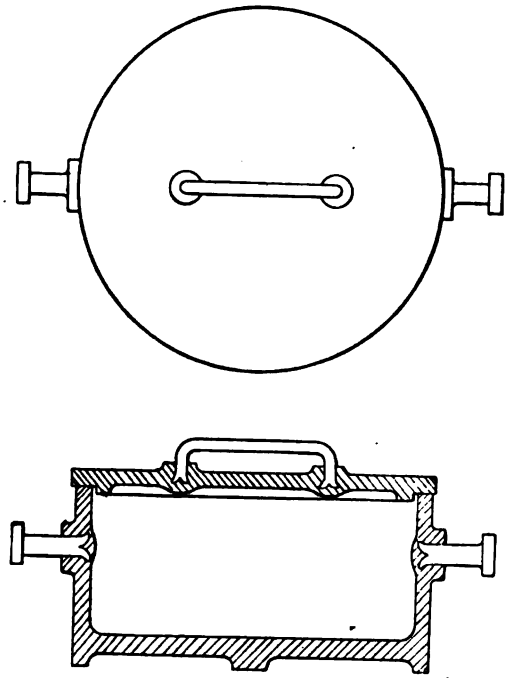


Fig. 126.—Box for Case Hardening.

colouring is often all that is required. Sometimes the two objects are combined. So too the methods used vary from the open fire, to boxes in various kinds of furnaces.

A cast-iron box suitable for general work in an engineer's shop is shown in Fig. 126. It has wrought-iron handles, or trunnions cast in, and the cover has a handle similarly cast. The metal is thick, from 1¼ inch to 2 inches, because it burns away in course of time. Cast boxes are more readily made of round form, because they can be swept up, than square ones. Wrought-iron boxes are lighter than cast, but more costly. The sizes of boxes for engineers' work range from about 8 in. diam. to 24 in. Wrought-iron boxes may range from 8 in. × 5 in. × 4 in. deep, to 26 in. × 16 in. × 9 in. deep.

There are two classes of materials used to effect the surface hardening. Potassium ferrocyanide, $K_2FeC_6N_6$, is a chemical substance which is used when small articles only have to be treated. Thus, an article is heated in the open fire, and the powdered ferro-prussiate of potash is strewn on the surface, and allowed to fuse, and then after a few minutes the work is dipped in water. If this is repeated two or three times, a slight surface hardening will be produced.

This however would be inadequate for most purposes, so that work is commonly enclosed in a box with crushed bone, charcoal, leather, horn, old belting, with a little prussiate, and salt, or saltpetre; the latter to intensify the action. The box is luted with clay, and allowed to remain in a furnace for periods ranging from a night to two or three days, the time varying with the depth of hardening required. About twenty-four hours is long enough for all ordinary work; the depth of case hardening will then range from $\frac{1}{32}$ inch to $\frac{3}{32}$ inch.

In the process of packing in the box, care must be taken to afford adequate support to the pieces, otherwise they will run risk of distortion when at a red heat. The shapes of the pieces must be considered in this. They must not only be supported by the packing material, but be laid in the direction in which they would be least liable to bend. The cementing material must be finer for small delicate work than with heavy. Every piece must have a layer separating it from other pieces, and from the sides of the box.

The practice of case hardening is an old one. In a paper on "Observations in Iron and Steel" in the "Memoirs of the Literary and Philosophical Society of Manchester," vol. v., part 1, 1798, page 109, the following occurs:—"Iron instruments are case hardened by heating them in a cinder or charcoal fire; if the first be used, a quantity of old leather or bones must be burnt in the fire to supply the metal with carbon. The fire must be urged by a pair of bellows to a sufficient degree of heat, and the whole opera-



Fig. 109.—15 Tons Cantilever Cranes, Barrow-in-Furness.

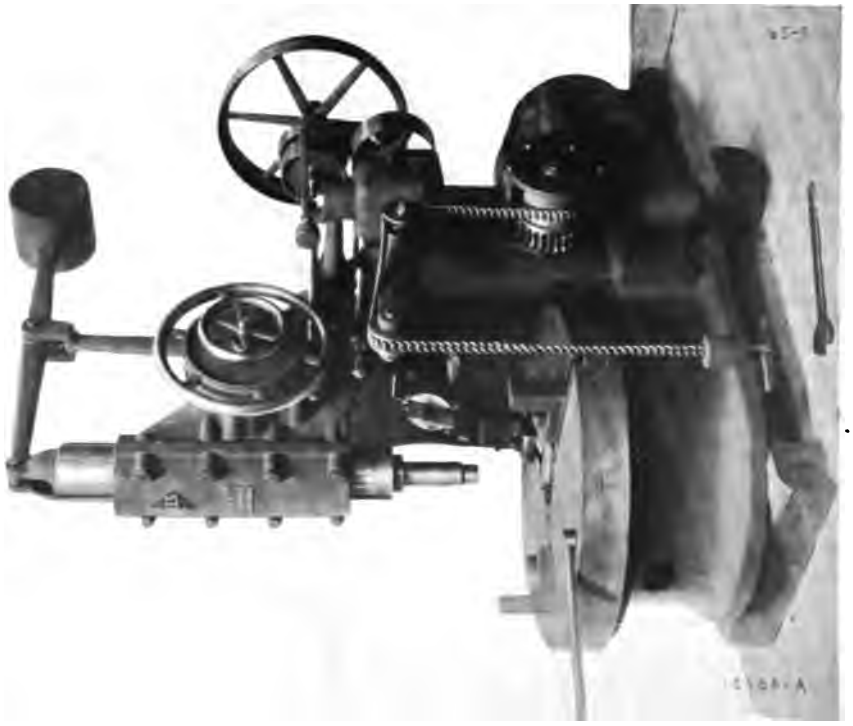


Fig. 125.—Car Wheel Lathe. (Niles-Bement-Pond Co.)

To face page 162.

tion is usually completed in an hour. The process for case hardening iron is in fact the same as for converting iron into steel, but not continued so long, as the surface only of the article is to be impregnated with carbon. Some attempts have been made to give cast iron by case hardening the texture and ductility of steel, but they have not been very successful. Table and pen knives have been made of it, and when ground have had a pretty good appearance, but the edges are not firm, and they soon lose their polish. Common table knives are frequently made of this metal."

Patents followed one another having case hardening for their object. The first apparently which covers the modern method was that of Dugdale (1849). He proposed the following:—"1 cwt. of charcoal, ½ lb. of borax, ¼ lb. of sal-ammoniac, ¼ lb. of saltpetre, or instead 1 lb. of salt." These materials pulverised were to be embedded with the iron in an air-tight box, and subjected to a red and white heat for several hours.

Dodds' patent in 1853 covered a furnace which in its essentials has been extensively used, Fig. 127. From the fire-grate A the heat passes through the flues *a a* around the retorts B B, thence into the arched chamber C, and on into four side flues D D, to the chimney E.

Vaughan (1856) proposed putting articles into a fused mixture of bichromate, or carbonate of potash, and chloride of sodium, with the object of protecting the work from the air, and from the products of furnace combustion. The practice is sometimes followed of immersing very delicate articles in a bath of the prussiate or the cyanide of potassium maintained at a red heat.

Brooman (1859) suggested baking the bones used, which practice is adopted generally in order to drive off the moisture, before enclosing the materials in the pots.

The objection to the use of miscellaneous mixtures employed in the general engineers' shops is that the results are not always certain and uniform, because of the different materials used, and their varying proportions. Hence the growing popularity of preparations of pure bone from which greasy matters have been expelled. A process is also adopted in which

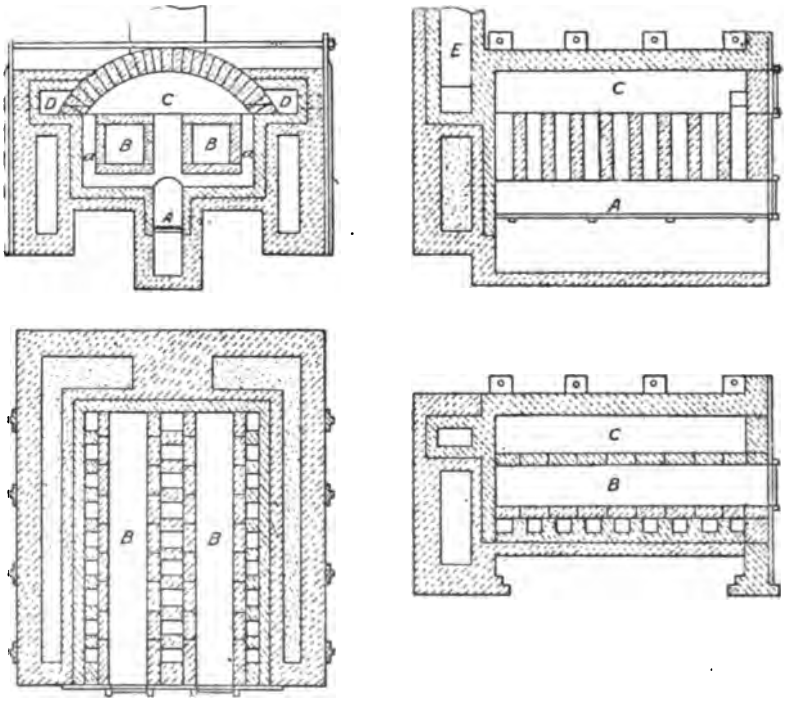


Fig. 127.—Dodds' Case-Hardening Furnace.

carbon is added to prepared bone. Granulated bone is supplied in different sizes to suit different grades of light and heavy work. It ranges from that which passes through ¼-inch mesh to that of ½-inch mesh.

Bone can be used again and again after drying it, if about a third part of new is added to the old. Spent bone can be used for the bottom and top layers in a box. Carbon is the principal hardening agent in bone, but phosphate of lime is present, which is also a hardening agent. If the heating process is continued after

the carbon is exhausted, and phosphorus is set free, this will produce brittleness.

Charred leather is not adapted for deep hardening, because its action is more rapid than that of carbon. When leather is used it must be cleaned from particles of metal, burnt to a cinder, and then crushed. Bone and leather may be mixed, or they may be placed in the box in alternate layers. Coarse charcoal powder is also used.

In packing work, a layer of from ½ inch to ¾ inch of spent bone or charcoal is laid in the bottom of the box, then a layer of the work, followed by successive layers of bone and work until within 1½ inch or so of the top. Then a final layer of bone or other material fills up the box. A cherry red heat is suitable for small work, a bright orange for larger pieces. The higher the temperature, the more care must be exercised in packing, because of the greater liability to distortion. When the process is over, the forgings must not be exposed to air, but as soon as the box is opened they must be turned over bodily and their contents emptied into a bath of cold water. Often the water has salt or saltpetre in solution to increase the hardening effect.

Case hardening can be repeated, and it is often better to harden in two or more operations than in one.

To test the depth of hardening, a tell-tale bar can be used, being a bar of the same material as the forgings, and thrust through a hole in the cover of the box. Being withdrawn and quenched, it can be broken, and the depth of hardening noted. Mild steel requires about one-fourth more cementing material than cast iron, and a longer period.

If a portion of a forging has to be left soft, it is encased in clay before insertion in the box, by which it is protected.

Very small articles are case hardened in a sheet-iron tray, having a layer of bone dust strewn over the bottom. The work being laid on this, and covered with another layer of bone dust, is heated to a cherry red for half an hour to an hour over a fire, and then thrown into water.

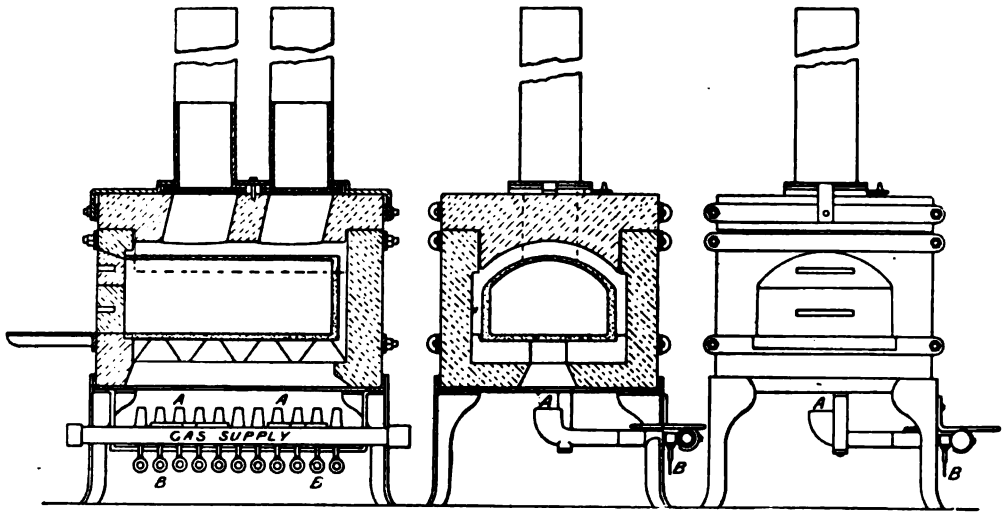


Fig. 128.—Draught Muffle Furnace for Case Hardening, &c. (Fletcher, Russell & Co., Ltd.)

Colour hardening is done by bone, which must be free from greasy matter. The heat must not exceed a cherry red, and the work must be thrown into water before the air can come into contact with it. The use of soft water is necessary. If articles have to be both coloured and hardened deeply, this must be done in two operations, the deep hardening first, the surface of the work cleaned, and followed by the colouring.

Gas furnaces.—The natural draught gas muffle furnace, shown by Fig. 128, is used for assaying

and tempering as well as for hardening. It is worked from 1,900° to 2,000° Fahr. For higher temperatures blast is required. Exact temperature is not necessary for case hardening, but if the furnace is used for tempering, a few degrees in variation is objectionable, and sometimes fatal to the best results, notably so in the case of milling cutters and fine springs. A gas-pressure governor is then fitted on the gas supply. The furnace is used either with a brick tray, or with muffles as shown, when contact with the gas flame is not desirable. In Fig. 128, A is the row of Bunsen burners, oblong in plan, and B the gas taps. The heat passes round the muffle on its way to the chimneys. Ordinary

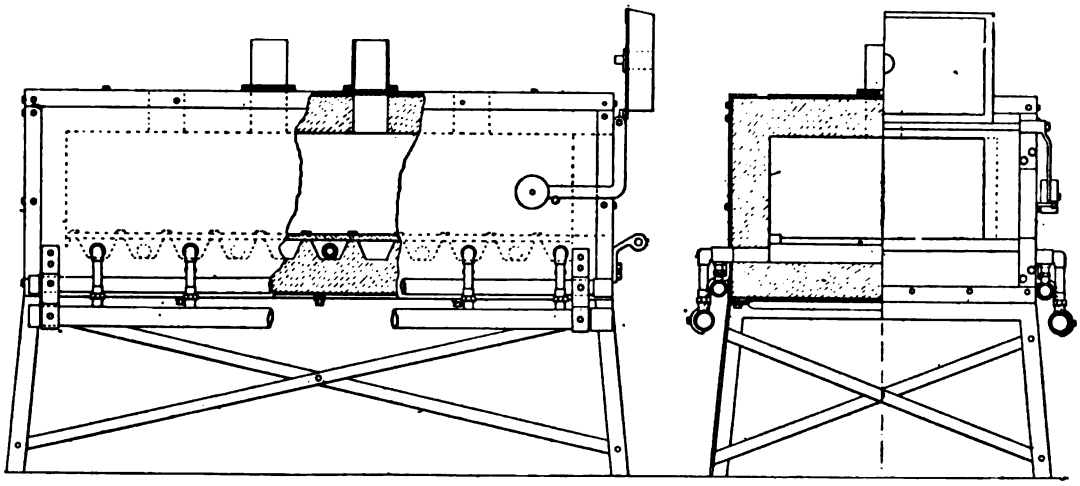


Fig. 129.—Case-Hardening Furnace with Gas Blast. (Fletcher, Russell & Co., Ltd.)

petroleum oil may be used, instead of coal-gas, or gasoline. Coal-gas and oxygen are only suited to the smallest sizes of furnaces. The highest temperatures are obtained by petroleum, and a Crowell, or other high-pressure blower driven by power.

These furnaces are made in eight sizes, in dimensions ranging as follows :—In the smallest, a clear inside working space of muffle of 2 in. wide × 2 in. high × 4 in. deep. In the largest, 20 in. wide × 6 in. high × 30 in. deep; the gas consumption per hour at full working power is 40 cubic feet in the first, and 420 cubic feet in the last.

For higher temperatures and faster working the "Cyclone" gas blast furnace, Fig. 129, is necessary, and is used largely for hardening cycle fittings. The rate of working and temperature depend entirely on the pressure of air blast available. This is shown fitted with a brick tray, but muffles are used for work where contact with the gas flame is undesirable.

Cask-making Machines.—A large number and variety of machines have been introduced for performing all the operations in the making of casks. A great deal of difficulty was formerly experienced in devising machines that would perform some of these operations satisfactorily, and there was also the usual difficulty in getting workmen and employers to take kindly to them, whether the economy effected was only slight, or unquestionably great. But the cask-making industry is so large, and also a continually increasing one, that it was long ago certain that it would eventually be appropriated entirely by machinery. At the present time hand cooperage is done only on a very small scale, and is a trifling industry compared with the output of machine-made casks.

The chief machines used in the business are those for preparing the staves, putting together, or trussing the casks, turning out the grooves for the heads, dressing the ends and exteriors, and preparing the heads.

Staves.—There are several methods of preparing the staves, and a great variety of machines are made for the purpose. In the first place,

staves are either riven, or sawn. The reason why the former method is often preferred is that the pores of cross-grain do not get laid open to the absorption of liquid, as they do when sawn. The advantage of riving, however, is often partially lost again by the necessity of trimming the staves approximately straight before they can be used. To prevent shrinkage as far as possible, and also leakage through the wood, the staves for tight casks are cut radially from the centre of the tree trunk. In this direction the shrinkage of the wood is a great deal less in amount than the circumferential shrinkage, and being in line with the medullary rays or plates, the staves are more impervious to moisture.

Staves may be cut perfectly flat, and bent to the radius of the cask, either in putting together, or before; or they may be sawn or planed to the curve. In the longitudinal direction, to give the required bilge to the cask, they are always bent, either in putting on the hoops, or before. When, as in thin softwood staves, the circumferential bending is done in putting the cask together, the edges are planed square, with the necessary taper from middle to ends, the radial inclination of the joints being given by the bending. When the staves are sawn flat and bent to shape before assembling, the bending is done by steaming, and putting them under pressure. Chambers for steaming, and presses for imparting the correct shape, both transversely and lengthwise, are used for this purpose. A method of assisting the bending at the time of putting together is to heat the inner faces of the staves, so causing those faces to contract and curl inwards.

In most casks the staves are too thick, and the wood too hard to be bent to the radius, and they are then either sawn to the curve by a cylinder saw, or sawn flat, and afterwards hollowed and backed by machines with revolving cutters for the purpose. The cylinder saw is the most economical method, both in material and time. It is a revolving cylinder of sheet steel with teeth cut at one end. The other end is firmly secured in a casting which may be compared to the chuck of a lathe, for it is driven in the same way by a shaft running in a sort of headstock behind it, and the whole, including a carriage for the wood, rests on a bed somewhat like that of a lathe. The wood is clamped on the carriage in the correct position, and brought endwise to the saw teeth on the end of the cylinder. The latter has to be long enough to cut the longest staves required, and cylinders of different diameters are required for casks of different sizes.

Joints.—In the machines for making the edge joints, either revolving cutters, plane irons, or saws are used, the latter being considered practically as good as the former if the saw leaves a finely cut surface. In most of the machines for this purpose it is necessary to have a cam, or a templet, in the form of a plate or bar with an edge of the same curve as that required on the edge of the stave. This either guides the cutter, or the wood towards and away from each other, as the cut proceeds from one end of the stave to the other, and so imparts the sweep which leaves the stave wider in the middle than at the ends. Another method of achieving this is by means of a disc machine in which a number of plane irons are set projecting slightly through slots in the face of the disc. There are two machines of this class; one in which the face of the disc is slightly concave to impart the necessary curve to the edge of a stave, which is clamped flat and presented to it, the amount of curve varying according to the distance from the centre of the disc; and the other in which the disc is flat, and the stave clamped on a block which bends it to the sweep it will assume when in the cask.

Machines are also employed for grooving and tongueing the joints of staves and heads, and also for planing the latter, and boring dowel holes at fixed distances in joints. Cross-cut saws are used for cutting staves to length. These may be of the ordinary type, in which an end is first squared, and a stop adjusted to fix the length while the other end is cut; or when this work is done on a large scale, both ends are cut simultaneously by a pair of circular saws, adjustable in relation to each other, on a splined shaft.

Setting-up. — The setting-up, or trussing machines are of various types, many of them operated by hydraulic power. They usually consist of a rising table with a ring round its

edge, within which the staves for a cask are arranged in a circle. The hoops are placed over the top of the staves, and a ring of catches or drivers depending from an upper part of the machine, and pressing against the sides of the cask, keep the hoops down as the table and cask rises. When the upper end of the cask is thus squeezed tightly together by the hoops, the table is lowered, the cask reversed, and the other end treated similarly. In another form of machine the cask and table remain stationary, and the hoops are pulled down by claws. In another the hoops are inserted in grooves in the interior of a hinged casting, which, when closed is the same size and shape as the outside of the upper half of the cask, and the rising table forces the ring of staves up into this. Simpler forms of machines are made in which a windlass, and rope encircling the ends of the staves, pulls them together, and the hoops are put on by hand.

Finishing.—Machines are employed for chucking the casks and cutting the grooves for the heads, trimming the ends, and smoothing the outsides if necessary. Others are used for rounding and bevelling the heads. In large heads for tight casks, a perfect circle when the head is new results in its becoming slightly elliptical after a time, owing to the shrinkage across grain, and absence of shrinkage with the grain. Such heads, therefore, have to be made elliptical when new, so that they will become true circles when shrunk. This is a detail which considerably complicates some of the head forming machines.

A number of machines and appliances are employed for minor operations connected with cask making. There are machines for shearing, punching, bending, splaying, and riveting hoops; for boring bung holes, making pegs, branding, hoisting barrels from one floor to another, and transporting them on the level. All machines and appliances vary considerably according to the kind of casks they are intended for.

Casting from Blast Furnace. — *See* **Direct Casting.**

Casting Ladle, or **Foundry Ladle.**— The vessel which receives molten metal, and from which it is poured into foundry moulds, or ingot moulds. Great improvements and increased complexity have been introduced into these of late years.

Ladles may be divided broadly into hand, shank, crane, and carriage types. They are cast, pressed, and built up with plating. They are plain tipping, and geared, are top, or bottom pouring. They are used chiefly in iron and steel casting, brass being generally poured from the crucible.

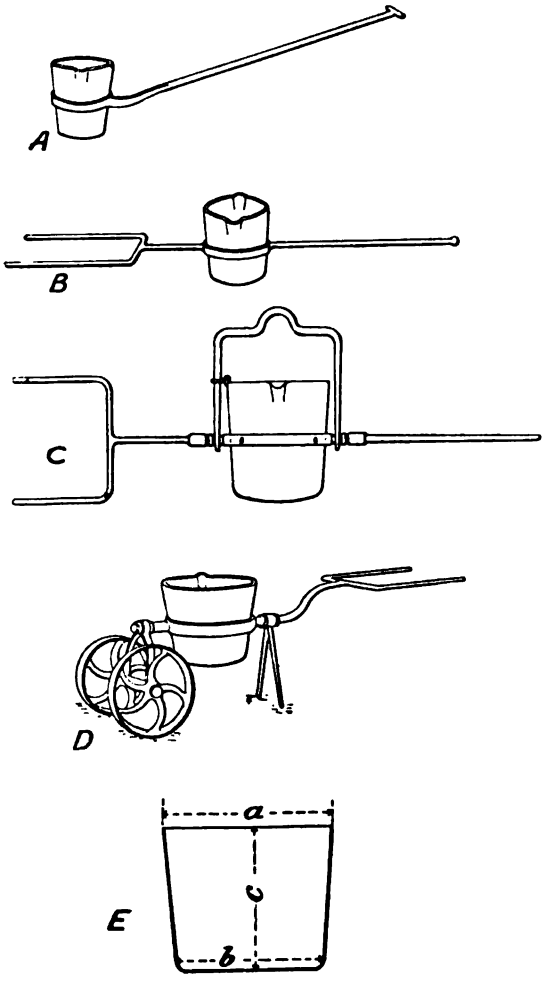


Fig. 130.—Casting Ladles.

Hand Ladles.—The smallest hand ladles, Fig. 130, A, hold about ½ cwt. of metal, and are carried and tipped by the hands of one man. Double shank ladles, B, hold from 1 to 4 cwt., and are handled by two, three, or four men. With 4 cwt. the limit to the hand ladles comes, and

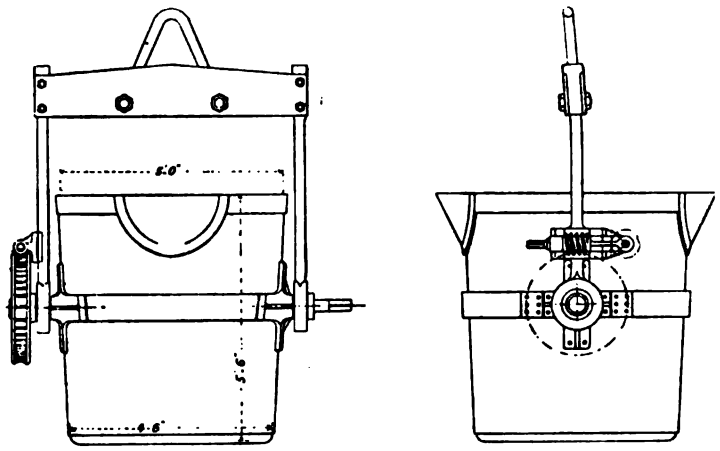


Fig. 131.—Crane Ladle.

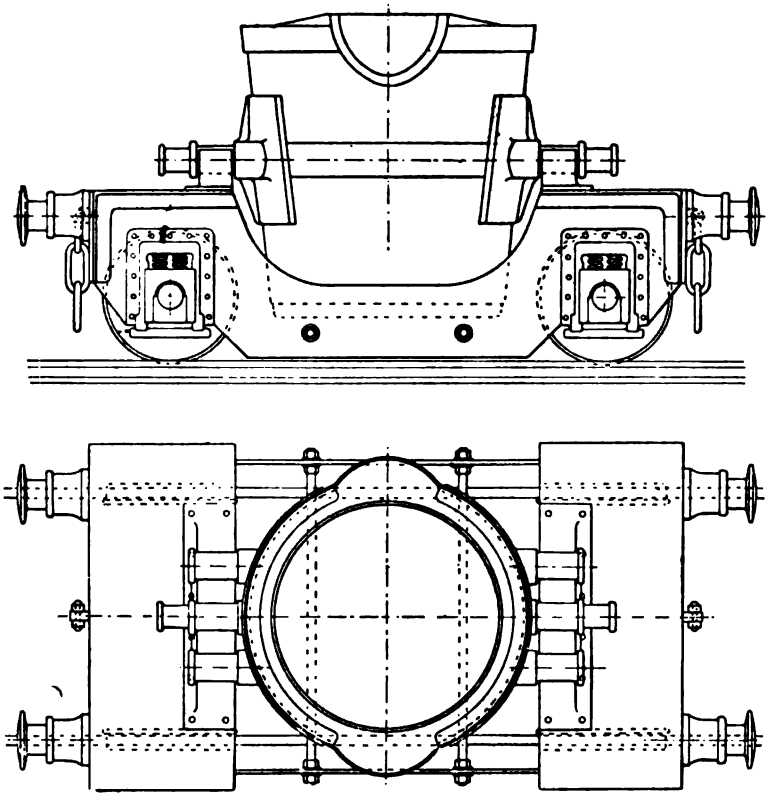


Fig. 132.—10-ton Side Tipping Ladle and Carriage. (Stevensons, Ltd.)

larger sizes have to be slung in the crane, or run on a carriage on rails.

Crane Ladles.—The crane ladles are small, or large. The small ones, Fig. 130, c, are tipped with a cross handle, by one or two men. The ladle is prevented from being overturned accidentally by throwing a catch over to embrace the bail. The maximum load of such ladles rarely exceeds from a ton to 30 cwt., because a larger mass of metal would be too much to be controlled by men exercising leverage at the cross handle. Beyond this the geared ladles are used, the invention of James Nasmyth. The gears comprise a worm and wheel only, Fig. 131, or a pair of bevel wheels in addition to gain power on the worm shaft (double geared). One man at the hand wheel is thus able to control precisely the movements of several tons of metal, which is a matter of much importance at the commencement of pouring when the basin is being filled, just before the metal is allowed to enter the ingates.

Carriage Ladles.—These are used for the transportation of metal about the shop as an alternative to carrying it with shank ladles, or slinging it in overhead travellers, or passing it from crane to crane with changing hooks. Corresponding with these alternatives, carriage ladles are made in all capacities from 1 ton to 60 tons capacity, with immense differences in detail.

The simplest form of ladle of this kind is the shank type, Fig. 130, c, with the shank supported in trunnions on a carriage. The next is the *barrow ladle*, or *sulky*, Fig. 130, d, run along on barrow wheels, and tipped sideways either to empty its contents into moulds directly, or to serve as a feeder to small hand ladles in its course, and so save men's time in running to the cupolas. Beyond this the carriage ladles are built in many designs numbering probably some dozens, which is accounted for by the fact that they are usually of a special character to suit the conditions of different foundries. The steel casting ladles are more specialised than those in iron foundries, the Bessemer and Siemens processes having made great demands on pouring devices.

There is very little cast iron in carriage ladles, but plating predominates. The trunnion pieces are cast in iron, or steel, and riveted to the plated ladle body. The carriage is either of plating, or formed of very massive castings. In the type, Fig. 132, it is fitted with axle boxes, and coil springs. In lighter designs, Fig. 133, plain axle bearings are used. Trunnion brackets are castings, and the bearings are sometimes open, sometimes capped. Wheels are of cast steel. Ladle carriages that have to travel rapidly are fitted with spring buffers at each end, Fig. 132, like rolling stock. Various arrangements are employed for travelling and for tipping; hand levers operating gears differently disposed. In others travelling is done with draw chains hitched on to locomotive cranes.

Ladle Capacity.—The capacities of ladles can be calculated by adding together the areas corresponding with *a* and *b* (*see* Fig. 130, e), taking the mean of the two, and multiplying by the depth *c*, and the result by the specific gravity of the metal.

Top, and Bottom Casting.—A cardinal difference between ladles is that of casting from the lip, by tipping as for cast iron, and for the supply of metal to Bessemer converters, and that of operating a spout at the bottom as for steel casting. The first may be a mere lip formed by bending the plate outwards, or riveting a lip or lips on, or a long shoot is riveted on.

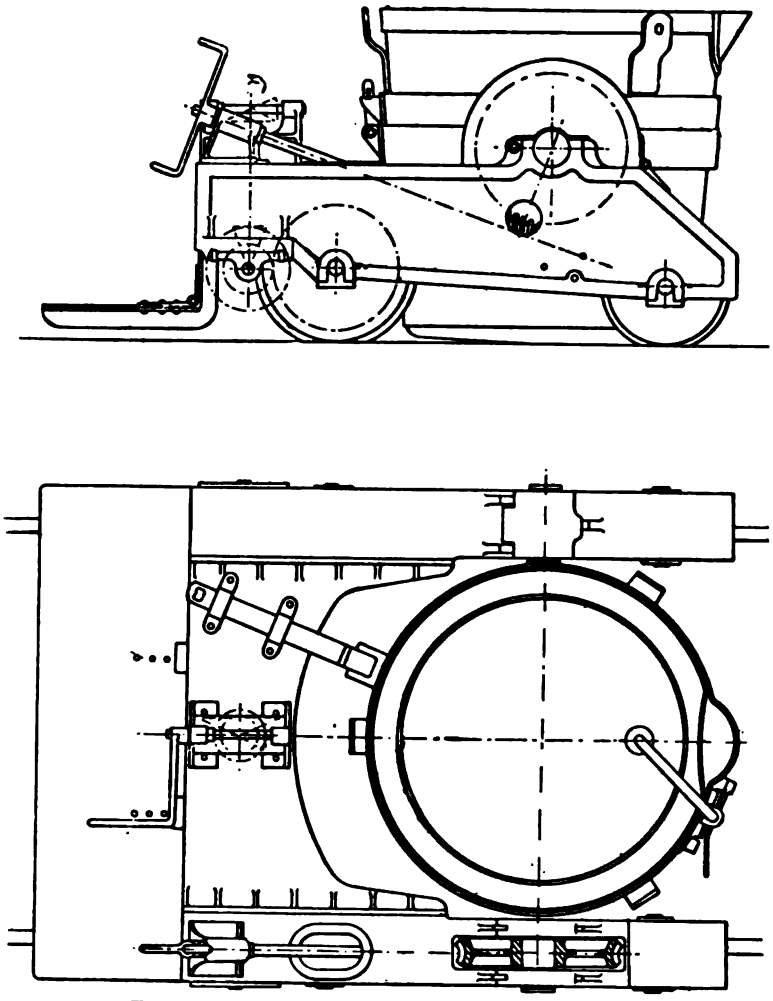


Fig. 133.—10-ton Carriage Ladle. (Stevensons, Ltd.)

A particular form of the first named is the *hot-metal ladle*, which brings the metal from the Bessemer cupolas to the converters. These have spring axle boxes, buffers, and screw gear for tipping, and lips are placed on both sides of the ladle so that pouring can be done from either side. A brake is also fitted to the travelling wheels.

Bottom casting for steel involves the fitting of a nozzle in the bottom of the ladle, through which the metal is teemed; a stopper and rod for opening and closing the nozzle, a goose neck for carrying the same, a sliding bar carrying the latter, and a lever for operating the mechanism; the arrangements of these vary in different designs.

Ladle Linings.—As molten metal must not come in contact with the plates of which the ladle is composed, they have to be lined with a refractory material at each time of casting. This is done overnight, or on the morning of use, so as to leave sufficient time for drying by heat. Fire-clay or loamy sand are used in ladles for cast iron. It is daubed on by hand, and blackwashed. Ladles for steel are generally lined with loam sand, and ganister, and the bottom lining is rammed hard. Large ladles have an inner lining of brick, but small ones only have the sand, &c. When bricks are used they are made specially for the purpose at Stourbridge, and are only from 1½ inch to 2 inches thick. In steel-casting ladles the stopper hole must be rammed with loam, and coated with a wash of fire-clay, and the stopper rod is enclosed in sleeves of fire-clay.

Slagging.—The accumulations of slag on the surface of metal in a ladle are one of the great difficulties incidental to pouring. Several devices have been proposed and adopted to get rid of this. The obvious everyday practice is to skim it, or bay it back with the edge of an iron rod at the time of pouring, and so prevent its entry into the pouring basin. Previous to this, however, when metal is hot enough to permit it to stand in the ladle for some time before pouring, the slag that rises is skimmed off at intervals of a few minutes. The dodge of filling up the pouring basin before allowing the metal to enter the ingate, and keeping it full till the pouring is completed, keeps back slag effectually; so does pouring with a skimming chamber. In iron casting these devices generally insure clean metal. But ladles have been devised for keeping the slag back, causing the metal to go down to the bottom of the ladle, and then up to the spout past a diaphragm. In steel casting the metal must be poured from the bottom, as in the goose neck ladle just noticed.

Casting Liners.—*See* **Liners.**

Casting Machine.—The Uehling machine appears to be the only successful type designed for the casting of pig from the blast furnace in a continuous manner. It takes the molten metal from a ladle car, transports, and pours it into travelling moulds, cools the pigs, and delivers them into railway trucks.

It consists of two endless chains, measuring about 90 feet long from centre to centre of the end sprocket wheels. To the chain links are bolted a series of iron moulds with edges overlapping one another, so as to form a continuous casting platform that moves at the rate of about 15 feet a minute. The machines are worked in pairs, two lines of moulds travelling side by side.

The iron is run from the ladle car through a T-shaped trough into the advancing moulds. After about six minutes, by which time the filled moulds will have reached the end of the conveyor, the pigs have set and cooled sufficiently to permit of their being dropped from the casting machine to a conveyor which takes them through a cooling tank filled with water, and then delivers them to the railway trucks.

The cooling of the pigs is facilitated while in the moulds by sprinkling them with water from a revolving distributor. As the empty moulds return to the casting trough they are coated with lime wash, sprayed against them. The pigs are thus not touched by hand, and being free from sand they are more economically melted than the ordinary pig.

The moulds are of soft grey iron, 22 in. long × 12 in. wide × 7 in. deep, with a thickness of metal of ¾ in. A mould will endure forty-five days of continuous work. A double casting machine handles 1 ton of metal per minute.

Casting on End or **Casting Upright.**—Relates to the pouring of long castings in cast

iron, steel, and gun-metal with the longer direction vertically, as distinguished from pouring it horizontally or "on the flat." It is adopted mostly in cylindrical work, and among this chiefly in steam and hydraulic cylinders, and in standard gas and water pipes.

In some cases it is more convenient to pour on end than horizontally, as in pipes of large diameter, foundation cylinders, engine cylinders swept up in loam, and other jobs of which these are typical. But that is not the case in long pipes, hydraulic cylinders, and columns; meaning by long, those the lengths of which exceed by several times their circumference. To cast these upright requires a pit, and special plant, which becomes more specialised the larger the number of similar castings required, until its highest development is reached in pipe-founding.

The object of casting on end is to secure metal of greater density than can be obtained by horizontal pouring, and to insure the metal being of more equal density, and clean. In some cases the getting of metal of equal thickness, without having to chaplet the centre core, is an important object sought.

Greater density is due to the hydrostatic pressure of the metal, increasing with height of head, or depth from the pouring basin to the bottom of the mould. This could only be obtained in horizontal casting by having an enormously high pouring basin, which is generally impracticable. Moreover an extra head of any height can be added in vertical pouring, leaving the entire finished casting sound, because poured under pressure.

With regard to metal of equal density, the difference between the density of the metal on the top and bottom of a pipe or cylinder poured horizontally may be considerable, and nearly always shows very marked in a fractured casting. The metal is more or less open or spongy in the top above the core, and this may easily in a steam cylinder reveal specks when bored, or cause leakage in hydraulic cylinders. Casting on end, the metal is alike all round.

The getting of metal of equal thickness is important in every circular casting; in steam cylinders in order that the bore shall hold up, in hydraulic cylinders to maintain strength, and in columns and pipes to prevent them from curving and coming out crooked. In hydraulic cylinders, chaplets are inadmissible; they are used in pipes and columns, but the cores then sometimes curve upwards, making the metal thin in the top, and curving of the casting results.

Apart from a special plant, casting on end is done in moulds that are rammed horizontally, and then up-ended into the pit. Back plates are bolted outside the bars of the box parts, to prevent the pressure from causing the sand to yield, and letting the metal run out. Holes must be cast in the top ends of the boxes for the entry of the metal from the pouring basin. Handles must be cast on the sides also for the sling chains to be hooked on for lowering into the pit.

Casting Pit.—A deep foundry pit in which deep moulds are set to be poured on end. Or a shallow pit for the pouring of shallow moulds, which also often combines provision for drying them by coke or gas. It may be a sand pit only, or enclosed with cast-iron plates bolted together. It may be parallel throughout, or contain successive stagings at different heights, of different diameters. Access is by a ladder. The advantage of the pit is that deep work can be poured upright without the top of the mould being much above the level of the foundry floor.

Castings—Curving of.—The curving of castings in cooling is a direct result of the shrinkage of metal. Castings that are equally proportioned do not curve, because the shrinkage takes place regularly, *i.e.*, to an equal amount everywhere, so that all sections cool down in the same time. Hence the desirability of equal proportioning. But since this is not always possible, the other course is to endeavour to frame some working basis on which to predicate, and to counteract the tendency to curve. This is only possible by observing the behaviour of work of this kind.

The first thing to be noticed is that disproportion in adjacent sections does not produce curvature unless the casting is of considerable length. Also, that thin light castings show the effects of shrinkage, in curving in a greater degree than heavy ones do. Of two girders, one 10 feet the other 20 feet long, both of the same section and heavy, the first may not curve at all in cooling, but the second will do so to

the extent of $\frac{3}{8}$ inch or $\frac{1}{2}$ inch. But a light casting of only from 4 feet to 6 feet in length will, if disproportioned, curve $\frac{1}{8}$ inch or $\frac{1}{4}$ inch in cooling. These facts show that camber must have considerable length in which to manifest itself, and that a large body of metal tends to counteract the curving effects.

If we look at the typical sections in the group, Fig. 134, we can compare various disproportioned castings that occur commonly in cast iron. The first, A, is a symmetrical one that gives no trouble, because the flanges are both alike. As long as these are of similar section it does not matter whether the web is thin or thick, narrow or wide, the casting will cool straight. But the next three sections will camber; C more than B, and D more than C, the reasons for which will help us to explain why camber occurs.

When B, C, and D cool the thin narrow flange cools first, shrinks and sets nearly rigidly, but not absolutely so, while the thick broad flange remains in a semi-molten state. Continuing to cool, and shrink, its outer face becomes concave, but the amount of this is controlled by the web adjacent. This is where the difficulty of estimating the amount of curvature comes in. Neither portion exists alone, but each is tied to the others, and its shrinkage and cooling is controlled by the others. We are sure that the web acts as a carrier of heat between the two flanges, and also as a stiffener, or rigid tie to them. It is necessary to bear this complication in mind in order to understand the differences in castings differently proportioned.

When the thin flange cools, it does not become cold, and set, because it continues to receive heat for some time from the large flange, through the medium of the web, and therefore the full shrinkage of which it is capable is not only delayed, but does not take place. Meanwhile the heavy flange goes on cooling and shrinking, and when it sets, it sets to its full amount, and the lighter flange is not able to exercise any effect upon it. Now here the reason becomes apparent why the breadth of web exercises much influence in results. The web in B is a good carrier of heat, C less so, and D least of all. But C is broader than D, and the flange of D will therefore curve more than that of C, for C is broad enough to resist the curving pull of its flange. E and F illustrate the same point. The thick flange in E will cause its web to curve both laterally and perpendicularly, concave on the top face. F will not curve its web in either direction, because the web is wide, and the flange is both light, and symmetrically arranged. Again, G and H differ in respect of the depth of flanges. Both will go concave on the face opposite the flanges. The amount of camber will depend on relative proportions. G, with a thin plate, will not curve so much as it would if the plate were much thicker than the ribbings. There is less tendency to camber in H than in G, because the deep ribs afford rigidity. As thickness is increased in the plate of H the concavity increases, because the plate is held on its inner face by the ribs, and the outer face alone can shrink to its full extent. Neither of these will curve laterally, but J will go concave on the face of the deep rib as well as on the face of the plate. A gutter casting, K, always goes concave on the bottom face, hence the patterns of these are cambered in the opposite direction.

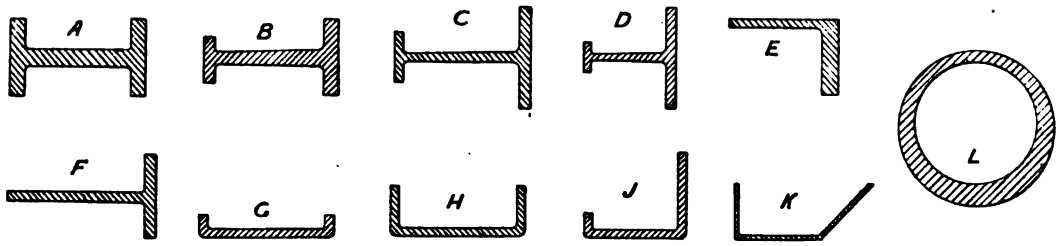


Fig. 134.—Curving of Castings.

In these examples we observe that the heavier metal becomes cambered to a concave shape on its outer face. But there is another class of work in which the opposite condition exists,

that of columns and pipes, where if a core gets out of centre, L, the thin side goes concave. This is doubtless due to the fact that no important transmission of heat takes place round the curves, and so the thin metal cools first and sets hard, and the thicker metal is afterwards held in bondage, and so is pulled to a convex form. If a pipe or column is uncovered on the top, the exposed part will assume and retain a concave form, even though the metal is of equal thickness all round. This bears out the explanation just given.

Camber in patterns is imparted in the opposite direction to that which the castings will assume, and to the same amount. The quantity required is either a matter to be determined by previous experience of similar work, or by an experiment with a first casting. It is imparted to patterns and to the bottom boards on which they are laid, when such are used.

Cast Iron.—This is an alloy of iron with carbon and other elements. In the proportioning of these elements lies the difference between cast iron, the steels, and wrought iron. In all of them the element iron amounts to considerably over 90 per cent., yet the effect of the alloying additions is to produce, in a wide range, practically entirely different materials.

Carbon is the most important element in cast iron in regard to the proportions in which it is present, and by its allotropic conditions. The difference between iron possessing its carbon in the graphitic and in the combined form would be astounding but for the fact that it is so common. It is the difference at the extremes between the hard white iron, and the soft grey variety, with all which this involves in foundry work.

We will first take the grades of cast iron from the foundryman's point of view, and then consider the present state of knowledge regarding this material.

Metal is broadly classified as grey, mottled, and white, each being well defined, and easily recognised. Each behaves differently when fractured, when melted, poured, and tooled, and each has its own utilities.

Grey Iron.—The fracture of good grey iron, say No. 1 Clyde, shows a coarse crystallisation, mostly large, of a dull bluish grey tint. Looked at by reflected light, darker lustreless spots appear intermingled, which are the flaky deposits of graphite, mechanically intermixed with the iron. Nearly all the carbon present occurs in this form in grey iron. When this iron is melted it is very fluid, it gives off no sparks, lies quietly in the ladle, and when the scum, comprising scales of graphite, is skimmed off, the surface shows a fine network of beautiful lines, "breaking" in quiet constant movement over the surface. Being very fluid, grey iron fills up the smallest impressions in moulds, and can be cast in very thin sections, as in rain-water pipes, and hot-water work. When cast in heavy sections the interior crystallisation becomes very much coarser than that near the surface. At the testing machine it shows more deflection than other varieties but less absolute strength, fracturing easily. It contains about 3 to 3·25 per cent. of graphitic carbon, with the barest trace of combined carbon.

White Iron.—The white iron lies at the opposite extreme. Its fractured surface shows long needle-like crystals, with an almost silvery whiteness, without a trace of those dark patches which indicate the presence of graphite. It does not show perfect fluidity when melted, but it runs thickly. It is in a state of ebullition in the ladle, throwing up minute waves, and scattering innumerable sparks, or "jumpers" off its surface. It cannot be poured in thin sections, nor will it run to a long distance in a mould, without becoming thick. It shows little deflection under test, but its strength to resist rupture is high. All its carbon, about 3 per cent., is in the combined condition.

Mottled Iron.—The mottled irons denote several grades of irons lying midway between the grey and white, and varying in the amount of mottle present. Such iron derives its name from the aspect of the fractured surface, which combines the whitish lustre with the darker specks of graphite, and the appearance of which varies in samples that approach more nearly the grey, or the white variety. Its carbon is divided in nearly equal amounts between the two varieties. In all their physical aspects, in the matter of fluidity, their appearance in the ladle, and under test, the mottled varieties occupy positions that lie between the grey and the white.

This is what might be expected, since most foundry irons comprise judicious mixtures of selected pig and scrap, melted and remelted with the intention of obtaining definite results. Nearly all the iron used for the best machinery castings is of some grade of mottled, inclining to grey. The stronger and better class of castings for cylinders, and parts subjected to wear and stress are decidedly mottled, but more massive pieces are of a light grey, consisting of No. 1 or 2 brands, with an admixture of machinery scrap. Repeated remeltings of grey iron cause it to become nearly white, and this has to be counteracted by additions of grey pig, or good open scrap. Two or three meltings of iron are sufficient to render it hard and inclined to whiteness, unless open scrap is added. The metal becomes more silicious, taking up the silicates from the fuel and the flux.

Volumes might be written about the action of the elements carbon, silicon, sulphur, phosphorus, and manganese in cast iron, but nothing more than a summary of facts can be offered here. The influence of neither element stands alone, and that is why statements have to be qualified constantly.

Carbon.—Carbon in foundry irons never exceeds 5 per cent. The maximum amount of carbon that iron can dissolve is about 4·25 per cent. It seldom exceeds 3·5 per cent. in pig, nor is it below from 2 to 2·5, since the metal would not then possess the characteristics of cast iron. The percentage of graphite may be varied without much affecting results. But very small variations in the amount of combined carbon alter the characteristics of the metal materially, rendering it more or less mottled, nearer to or farther removed from white iron. The allotropic state in which it is present is largely controlled by the presence of silicon, a fact which was hardly suspected by the early founders, but it has opened up a field which has since been enriched by the labours of Turner, Wood, Stead, Gautier, and Keep. Dr Percy long ago pointed out that "from the close chemical relations between these two elements, it is reasonable to anticipate that they might, at least in a certain degree, replace each other." He also mentioned the fact that it is in graphite iron that the largest amount of silicon is generally found. Sefström had observed "that the carbon in grey iron in which much silicon exists, say from 2 to 3 per cent., is wholly, or nearly so in the graphitic state." This field, however, lay unworked until 1885, when Thomas Turner published a paper on the subject.

Silicon.—Silicon has a greater affinity for iron than carbon has, and its presence changes carbon from the combined to the graphitic condition. Hence silicon added to white iron, and to inferior iron that has become deteriorated by repeated remeltings, will change the carbon to the graphitic state, in other words will produce grey iron.

This statement was for a long time received with incredulity, and people said that the resulting iron was rotten. But the value of the addition has been established, and ferro-silicon is employed for addition to inferior irons. Conversely the expulsion of silicon from grey pig causes the conversion of graphite into combined carbon. So it follows that though silicon itself is not a desirable element in cast iron, and in excess produces a very poor material, as in the blazed, or glazed pig, yet used judiciously it has become a most valuable ally to the iron founder. The silicon occurs as a silicide, having the composition Fe_2Si, or FeSi, or $(FeMn)_8Si$.

Too much or too little silicon in cast iron are equally harmful. It must be proportioned to suit the class of iron required. It is largest in amount in the greys, ranging from about 3·5 to 2·5 per cent., the larger content occurring in the greyest, ranging thence to about 1 per cent. in mottled, and about 5 or 6 per cent. in white. An excess of silicon renders metal crystalline and brittle. Rich ferro-silicons can be broken to powder under the hammer. The fact that they vary in degree of fusibility and in density from ordinary iron renders their use difficult. The size of the graphite is affected by the addition of silicon, so that its flakes are of smaller size than those which exist in the ordinary pig. The metal therefore being of closer texture, is stronger. Owing to the difficulty of effecting regular mixtures with ferro-silicons, it is still generally preferable to adopt the iron founders' old-fashioned plan of selecting and mixing hard and soft irons with scrap, in order to obtain all the grades wanted. Though silicon is a softener

of cast iron, it does not follow that iron so softened is to be preferred to that originally soft. The question often resolves itself into one of cost, since ferro-silicons are dear, and the range of their utilities is limited. Oyster shells have long been used for softening.

Sulphur.—Sulphur is not a desirable element, except in small amounts, when it helps to produce a mottled iron. In excess it tends to produce hardness and whiteness. It counteracts the influence of silicon, and is favourable to the resolution of carbon into the combined condition. It is said that one part of sulphur will neutralise the effect of ten parts of silicon. ·10 per cent. is the maximum of sulphur allowable, but from ·03 to ·07 per cent. should seldom be exceeded. It is a troublesome element, the cause of many wasters, and is unequally distributed as a sulphide of iron through the mass of a casting.

Phosphorus.—The only value of phosphorus lies in the fact that it renders iron fluid, and is therefore helpful in pouring very fine castings. But in large quantities it diminishes strength and renders the metal brittle. It is found to the extent of about 1·5 per cent. in most irons, being practically constant in the whole range from grey to white, but it should be lower for specially strong castings. Phosphorus is inadmissible in iron for ingot moulds, as its eutectic is fusible at a high temperature.

Manganese.—Manganese is of little value in iron, though it is essential in steel. It ranges from about ·6 to ·7 per cent. in foundry irons. We need take no account of the elements, traces of which are often found in cast iron, as titanium, arsenic, copper, and some others.

Recent researches.—These appear to have established the fact that the graphitic carbon occurs in two forms, in the ordinary flaky condition, and in another, a powdery state. The latter is termed temper graphite, or amorphous carbon. The interest of the latter lies in the probability that as it is not separated in large flakes it produces stronger castings than the ordinary graphitic form. The combined carbon in white cast iron exists in two forms, one of which is capable of resisting the effect of cold hydrochloric acid. This is termed *missing* carbon, or *cement* carbon. The term *cementite* is applied to the white base on which a pearl-like structure, *pearlite*, of a dark pattern is apparent. Chemistry knows nothing of these distinctions, but they may lead to practical results in metal mixing.

Cast-Iron Pipe.—Is used for the conveyance of water and gas chiefly. It is made in standard lengths, 6 ft. generally in sizes below 3 in. bore, and 9 ft. in sizes above 3 in. up to about 12 in. Pipes above that dimension may be made to requirements, as they are not stock sizes.

Cast-iron pipe is designed not so much for the pressure which it has to withstand, for its strength is generally far in excess of that, but to resist chance of fracture due to uneven setting, the rolling of traffic above it, and the faults incidental to casting. The pressure test is adopted, but it is immensely in excess of any pressure that the pipes will have to withstand. When pipes fail under hydraulic test it is not often by fracture, but in consequence of openness of the metal, or the presence of blow holes. The water pressure finds out such places, and spurting out, reveals the fault. Sometimes the part is burred over and closed by the hammer sufficiently to prevent escape of the liquid, but this is only possible in the absence of personal inspection. During the imposition of the water test, an assistant taps over the pipe lightly with a hand hammer to find out and start any place of incipient leakage. The foregoing remarks relate to the water and gas mains that are laid beneath roadways. The hot-water and rain-water pipes are of a different kind, being subject to scarcely any pressure, and being in the open. They are made as thin as the metal will run, or from $\frac{1}{8}$ inch to $\frac{1}{4}$ inch.

Pipes are united by different methods. For the standard run of great lengths, the socket and spigot form of joint is almost universally employed. It has the advantage over flanges in permitting of a little departure from alignment without interfering with the jointing. The spigot has play in its socket, and the amount left for stemming with lead and gasket will range from $\frac{3}{8}$ inch to 1 inch all round in smaller, and larger pipes. Bend pipes and tees are united with spigot and socket joints. Valves are made to suit the same kind of joint.

Or flanged pipes may be inserted where valves have to come.

Fig. 135 shows various pipe connections. A is a quarter bend, with spigot and socketed end. B is an eighth bend with similar ends, C is a quarter bend with flanges, D is an S-pipe with socket and spigot, E an S-pipe made by bolting two flanged bends together. F to J are various tee-pieces with different end attachments, and varying in the position of the branch and radius of the throat.

The methods of manufacture of cast-iron pipe depend mainly on the qualities of a given size demanded. There are the jobbing, and the regular shops, and the methods differ in many respects.

In the jobbing shops where pipes are manufactured of all lengths to suit, say, a firm's own class of work, or the requirements of a district, patterns are made of wood, and a large amount of cutting, making up, and stopping off is done. Cores are generally swept up in core sand on bars, with hay bands, or strickled on core plates. Large pipes are made from loam patterns. Little or no assistance is derived from joint boards. Moulds are poured horizontally.

In the regular shops metal patterns are mostly employed, and metal core boxes for the smaller pipes. Standard patterns are not altered for small orders. Pipe moulds are poured on end, or at an angle on a "bank." Large cores are generally swept up on collapsible core bars, without hay bands intervening. Special plant is laid down for making the moulds and for pouring the metal.

In the thin pipes for hot-water metal, patterns are used unjointed. Cores are rammed in green sand in boxes. Special arrangements are made for casting.

Castor Oil.—Used as a dressing for leather belts, to keep them supple and prevent cracking. It has to be used very sparingly, as excess is objectionable.

Cast Steel.—An alloy of iron which is melted and cast. Steel made by the cementation process, melted in a crucible, is **Crucible Cast Steel.** Pig iron, decarburised and recarburised in a converter, is **Bessemer Steel.** Cast steel is also produced in the **Open Hearth** processes. Practically all steel now used, the shear steel excepted, is cast, irrespective of subsequent treatment by rolling into plates, bars, sections, &c., the metal being teemed first of all into ingot moulds. The great advantage of such steel over forged iron, apart from its greater strength, is its homogeneous character. Fusion accomplishes at once that which is obtained more laboriously, and with less certainty in an iron that never gets beyond the pasty condition.

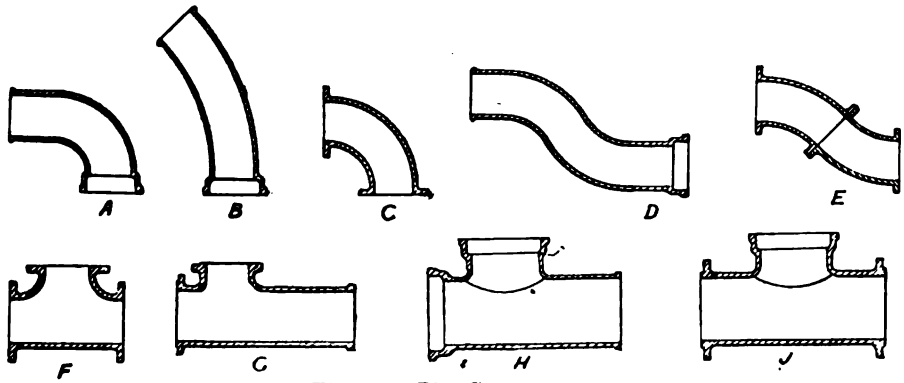


Fig. 135.—Pipe Connections.

Catalan Forge.—A crude smelting furnace for iron in which charcoal is the fuel used. It is employed in the French Pyrenees and in Spain. Blast is applied by a trompe or water-blowing machine. The reactions are similar to those which occur in the blast furnace, and the product is malleable iron, the temperature being too low for the production of cast iron. It is very wasteful, three or four tons of charcoal being required per ton of hammered blooms.

Cataract.—The cataract is merely a modi-

fied dashpot, and is a sort of water clock. It consists of a cylinder fitted with a piston, and the two ends of the cylinder are connected by a pipe, in which is an adjustable cock, or valve, by which the passage of a liquid from end to end of the cylinder can be regulated. The liquid is forced round by weighting the piston, and the apparatus was employed to regulate the number of strokes of the Cornish engine, the steam valve being only opened when the cataract had gone through its stroke. The engine having made its stroke, re-set the cataract gear automatically, as can readily be arranged by means of a non-return valve in a second by-pass pipe, and the speed was thus regulated by adjusting the rate of flow by the timing cock or valve. In modified form the cataract becomes a dashpot for controlling the rapid movement of governors, &c., in the way of checking momentum, and yet without affecting total proper movement.

Catch Pawl.—*See* **Pawl.**

Catch Plate.—Another name for the face-plate form of **Driver.**

Catenary Curve.—The curve which a chain or cord of uniform substance and texture assumes when it is hung upon two points of suspension, whether those points be in a horizontal plane or not, and is free to adjust itself in equilibrium in a vertical plane. It is of interest on account of its connection with suspension bridges.

Cattle Gear.—The same as bullock gear or horse gear.

Caulking, or **Calking.** — Rendering the joints of riveted work in iron and steel, water, and steam tight by a slight burring up of the edges of the plates. It is effected by blows delivered through the medium of a narrow blunt-ended tool, Fig. 136, B, C. The end is flat and roughened up to prevent it from slipping. Its thickness at the edge ranges from about $\frac{3}{16}$ inch to $\frac{3}{4}$ inch. Those having wider edges, A, D, are termed fullering tools. The end is not quite square up and down, but is slightly bevelled. The tool is generally used first with the acute angle turned towards the outer face of the plate to be caulked, so as to slightly bevel the edge of the plate, and then the tool is reversed and the narrow caulking done.

The great points to observe are, not to force the plate open by thrusting it upwards with a narrow tool, and not to drive a narrow tool too much downwards, so causing it to cut into the surface of the plate adjacent. Forcing plates apart is a fruitful source of future corrosion, and nicking the plate will result in after grooving, and furrowing. The work of the caulker is much helped by planing the edges to be caulked, and to a slight bevel.

After two or three blows have been delivered on the caulking tool, it is moved along for about two-thirds of its width so that the surfaces shall overlap and the caulking be thus continuous. For very heavy caulking a handled tool is used struck with a light sledge.

Rivets are caulked in fire-boxes, but not in

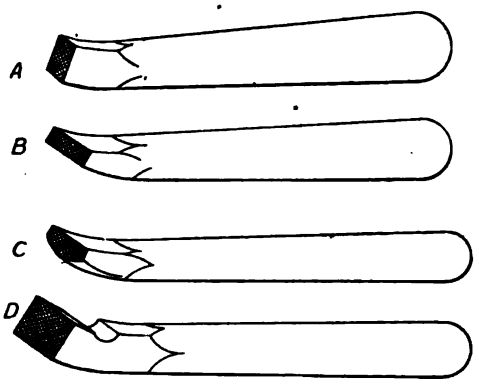


Fig. 136.—Caulking Tools.

shells unless they show leakage under test. A special tool is used for this work, being convex on the back.

Pneumatic caulking has superseded hand work to a large extent. *See* **Pneumatic Caulking Tools.**

Caulking, or *stemming*, or *staving*, or *yarning*, relates to the jointing of water and gas pipes in their sockets. Lead, or gasket is the jointing material, inserted between a spigot end and a socket. The tools used are struck with a hammer so driving the material tightly. The forms used include the bent form, Fig. 137, A with a flat stem, and B cranked with a curved stem, and C offset or side cranked, curved in the opposite direction to B. D and E are shipwrights' caulking irons for oakum, D is a double crease iron, E is a bent

or cranked type. For Caulking Mallets, *see* **Mallets.**

Caulking Ring.—When cast-iron mouthpieces are fitted to boilers, as the edges of the cast iron cannot be caulked, it is necessary to insert a ring of wrought iron, or steel about $\frac{3}{8}$ inch in thickness between the cast flange and the boiler plate, around the edges of which caulking is done.

Caulking Strip.—A strip of sheet metal the edges of which have to be caulked. Butt straps are caulking strips.

Caulking Tool.—*See* **Caulking.**

Caustic Potash.—Hydrate or hydroxide of potassium, KHO. Familiar as the white, crystalline sticks possessing highly powerful caustic properties when applied to the skin. KHO is largely prepared by the action of lime on potassium carbonate, K_2CO_3. Calcium carbonate is formed and sinks to the bottom, the solution is evaporated, leaving caustic potash :—

$$K_2CO_3 + Ca(OH)_2 = 2KHO + CaCO_3.$$

It is extremely deliquescent and is so soluble that it requires only half its own weight of water for solution. It is of great importance in the manufacture of soap.

Caustic Soda.—Hydrate or hydroxide of sodium, NaHO, is very similar in its properties to caustic potash, but somewhat less powerful in its physiological action. NaHO is also prepared in the same way as the corresponding hydrate of potassium by boiling carbonate of soda and lime :—

$$Ca(OH)_2 + Na_2CO_3 = CaCO_3 + 2NaHO.$$

It is very soluble in water and is used in soap manufacture.

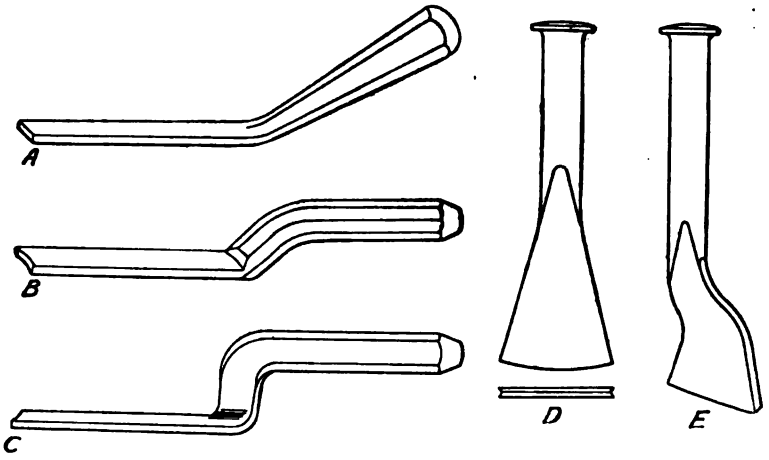


Fig. 137.—Caulking Irons.

Celluloid, or Xylonite, also called Parkesine from the name of the inventor, a Mr Parkes, who first made it at Birmingham in 1856. It is prepared from cellulose—the main constituent of vegetable tissues—in the following manner:—Cotton, paper, rags, or other vegetable matter is immersed in a mixture of strong acids, generally 4 parts of sulphuric to 1 part of nitric acid. This is identical with the process of preparing gun-cotton, except that the proportions of acid in the manufacture of the explosive are 1 of nitric and 3 of sulphuric. After sufficient time has elapsed for the paper, rag, &c., to become saturated, the acids are drawn off and the nitrocellulose compressed to eliminate the absorbed acid. It is next washed and bleached and then placed in some such solvent as alcohol, or nitro-benzol, being also treated with camphor, castor, or cotton-seed oil, and—if necessary—dyes, and finally the doughy mass is passed between heated steel rollers. All traces of the solvent used are eliminated either by drying the celluloid in heated chambers, or by treatment with bisulphide of carbon, or chloride of lime, the former process taking several days or even weeks.

The uses of celluloid are legion—combs, backs of brushes, set squares, rules, and protractors for draughtsmen, piano keys, knife handles, billiard balls, buttons, napkin rings, toys, scientific instruments, thimbles and imitation coral, tortoise-shell, and amber. The last-mentioned purposes to which celluloid has been put are due to the ease with which dyes are introduced during the process of manufacture.

Its natural colour is buff, but it can be made transparent or variegated. Celluloid may be made of varying degrees of hardness; is unaffected by air or water; becomes plastic when heated (125°); and portions can then be joined together by pressure of the finger; it can also be spread over cloth when plastic. The great disadvantage connected with its use is its inflammability, a highly dangerous property in such articles as dolls, collars, and toys. Non-combustible ingredients have been used in the manufacture of celluloid but so far with little or no success.

Cement.—Cements, excluding the lead oxides and similar cements of the mechanical engineer, are classible as artificial stones. They consist of certain earths so compounded that when mixed with water, chemical action takes place, and there is absorption both of water and of carbonic acid gas, the water forming crystals with the earthy matter, and the carbonic acid forming carbonates.

Thus a paste of lime will harden if it can absorb carbonic acid gas from the atmosphere, the caustic lime becoming crystalline carbonate of lime. The action is quickened and rendered more complex when silica and alumina are present; and limestone burned with an admixture of silica and alumina in close union and subsequently ground has the power of becoming hard under water. It is then said to be an hydraulic lime. Impure limestones occur in nature, which when burned are already more or less hydraulic. Such are the Lias limestone, the septaria of the London Clay, and others. From the first is made the celebrated Lias lime, from the second, Roman cement.

Portland cement is entirely artificial, and is made by adding to limestone such a proportion of silica and alumina as will form the best cement. Natural limestone such as chalk is a carbonate of lime, $CaCO_3$, and is converted into CaO or caustic lime when highly heated, the CO_2 being driven off as gas. Mixed with water, caustic lime hydrates to a soft paste with great evolution of heat, *i.e.*, $CaO + H_2O = Ca(HO)_2$. Calcination of a clay limestone may be carried out so as to produce either a hydraulic lime, a quick-setting cement, or a cement like Portland. Much depends on the temperature of the kiln, for the subsequent chemical or setting process is different.

Medway mud, which is the clay constituent of Thames-made Portland cement, contains about 64 per cent. of silica, or SiO_2; 16 per cent. of alumina, or Al_2O_3, and 7 per cent. of iron oxide, the remainder being small and fractional parts of numerous other substances. Chalk contains sometimes over 98 per cent. of pure carbonate of lime. These two substances, clay and chalk, properly blended, kilned, and ground, will produce a slaty blue true Portland cement, which should contain 60 to 66 per cent. of lime, CaO, and 40 to 34 per cent. of silica and alumina, &c.

Here is an analysis of a cement clinker as it came from the kiln:—

	1	2
Insoluble residue -	0·21 °/.	2·36 °/.
Silica - - -	27·16	18·43
Oxide of iron -	4·42	4·45
Alumina - -	6·57	7·23
Lime - - -	58·33	65·44
Sulphate of lime -	0·33	0·16
Magnesia - -	1·17	1·91
Loss on ignition -	1·54	0·18 alkali.
	99·73	100·16
? Alkali, &c. -	·27	

Lime sulphate promotes slow setting and is apt to be dangerous, especially when magnesia is present. Its effect wears off.

Le Chatelier gives a formula for good quality analysis as follows:—The lime must not exceed

$$\frac{CaO + MgO}{SiO_2 + Al_2O_3} = 3$$

nor be less than

$$\frac{CaO + MgO}{SiO_2 - Al_2O_3 - F_2O_3} = 3,$$

the formula being in chemical equivalents, not weights.

Dr Erdmeyer says magnesia, however, may not be counted as lime, and would strike it out of the formula, and he says many good cements show $\frac{CaO}{SiO_2 + Al_2O_3} = 2{\cdot}5$.

Thus a good mixture will contain 75 to 76 per cent. of carbonate of lime before burning.

The question of the condition of the various

elements in a cement is too involved for brief treatment, but Portland cement is held to contain a monocalcium silicate $CaOSiO_2$, a dicalcium silicate $2CaO.SiO_2$, and a tricalcium silicate, as well as the three corresponding calcium aluminates $CaO.Al_2O_3$, &c., which all set in water and produce the initial set of cement. Various interchanges of these substances when setting take place with more or less rapid hardening, without absorption of carbonic acid except so far as may perhaps take place slowly. The whole question of setting is still *in nubibus*.

After cement has been burned the rough clinker may be dampened to rid it of the effect of any underburned portions by hydration, prior to grinding. It is then ground to a fineness which is specified by the Admiralty as "to pass through a $50 \times 50 = 2{,}500$ meshes per square inch made of brass wire 0·007 inch diameter, with a residue of not more than $2\frac{1}{2}$ per cent. by weight, and not more than 10 per cent. on a sieve of $76 \times 76 = 5{,}776$ meshes of brass wire 0·005 inch diameter." Hoyle's grinders will grind easily several times finer than this.

The cement, when made into testing briquettes with a central minimum section $1\frac{1}{2}$ in. $\times$ $1\frac{1}{2}$ in., must then carry a load of 350 lb. per square inch when seven days old, the stress being applied at the rate of 100 lb. per fifteen seconds. The cement should have a specific gravity of 3·15 when freshly ground, or 3·10 after some lapse of time, and it must not contain more than $1\frac{1}{2}$ per cent. of magnesia or 2 per cent. of sulphuric anhydride.

Of late years great endeavours have been made to use other substances than chalk and clay for cement making, notably blast-furnace slag with an addition of lime. Also the ingredients of cement are initially mixed wet or dry according to their nature and general properties. Cement is burned in both plain and rotary kilns, and with coke, coal, or oil fuel, all of which have their effect on the percentage composition of the finished cement. At the time of writing, the cement industry is passing through a period of change and uncertainty, the method of burning in rotary kilns producing a different sort of clinker, which possesses very quick setting properties unless hydrated to some extent so as to change the aluminates at an early point in the life of the cement. The "rotary" clinker is tough and much more difficult and costly to grind, and altogether the cement art is in a transitional uncertain stage.

Roman cement is the result of kilning the septaria or claystones of the London Clay, and grinding the burnt product. It is a light, quick-setting brown cement, and at once hardens when mixed with water, so that it is often usable in situations where it is only possible to protect it from water spray for a few minutes. In careful hands Roman cement has produced excellent work.

Gypsum cement, or plaster of paris, is produced by burning natural gypsum or sulphate of lime until its water of hydration is driven off. The kilned product, when ground, is called plaster of paris, and it is a quick-setting cement for indoor work, the finer pure white qualities being used for statuary, &c. The cheaper qualities are stained with the red marl in which the gypsum is found.

Keene's cement is made by soaking half-kilned gypsum in alum solution and reburning. The burned or half-burned lumps are cleared of their burned surfaces, and again soaked and kilned. Parian cement is a similar product. These alum-soaked cements set very hard and take a high polish, and are used for better class interior decorative plaster work. Unlike ordinary lime plasters, the gypsum cements set at once, dry rapidly, and have no long-continued external effects, and may at once be painted, coloured, or papered upon.

Slag cement is a varied product. Some slags are mixed with the amount of lime necessary to bring them up to "Portland" proportions; others are said, if cooled properly, to be fit for direct grinding into a cement claimed to be equal to Portland.

Rosendale cement is a natural American Portland of the nature of a powerfully hydraulic lime.

Cementation.—Signifies the permeation of iron with charcoal (the cement) and its resulting conversion into steel, or steely iron. It is the method which has been employed from immemorial ages, since wootz was first made in India, up to the present day when shear steel is

the product obtained in Sheffield furnaces. The Hindoos make wootz, as their ancestors did, by the prolonged heating of malleable iron in closed crucibles along with the chopped leaves and stems of certain plants. The product contains about 1·6 per cent. of carbon. The Sheffield steelmakers heat bars of malleable iron in large pots in contact with wood charcoal in a converting furnace. The principle is identical, the details are changed. In each case, at the prolonged high temperature, the carbon penetrates and amalgamates with the iron, converting the tough fibrous iron into a steel alloy of iron and carbon, not homogeneous nor fit for use until it is tilted or hammered, or cast. The *cement steel*, or *blister steel*, or *blister bars*, so called because of the small surface blisters with which the bars are covered, is made as follows :—

A converting furnace, one of those conical glass-houselike structures so ubiquitous in Sheffield, comprises an oblong chamber covered with a fire-brick arch. It is divided longitudinally by a narrow fire-place, with a fire-door at each end. Flues run thence in horizontal and vertical directions to the short chimneys, which discharge their contents into the conical hood surrounding. Over the network of horizontal flues, and supported on bearers of masonry, two open-topped converting pots of fire-stone are laid, about 18 in. apart, and the entire length of the furnace. These pots measure from 8 ft. to 15 ft. in length, an average being 12 ft. Generally the pots measure 12 ft. × 4 ft. × 4 ft. They are built of slabs of a peculiar kind of fire-stone obtained in the neighbourhood of Sheffield, which has the property of not cracking when heated slowly to a high temperature, and allowed to cool slowly. A pair of pots will last from twenty to forty meltings before they have to be replaced by new ones.

The bars are charged through a manhole at each end, just above the pots ; and a hole in one end of each pot, and through the furnace wall corresponding, is used as a tap hole for the insertion and removal of trial bars.

The charging is done as follows :—Bars of hammered or rolled iron from 6 ft. to 12 ft. in length, by about 3 in. by $\frac{5}{8}$ in. to $\frac{3}{4}$ in. are laid flatwise on a prepared bed of charcoal spread in the bottom of the pot to a thickness of about $\frac{1}{2}$ in., with a space between the edges for more charcoal. A layer of charcoal follows of about $\frac{1}{2}$ in. thickness, and so on, bars and charcoal alternating, finishing with charcoal. The surface is then covered with wheelswarf—the mud from the grindstones, which being highly silicious, fuses and forms a glazed air-tight covering. The charcoal used is sifted through a riddle of $\frac{1}{2}$ in. or $\frac{3}{4}$ in. mesh ; and equal proportions of new charcoal with that which has been used from a previous charge are more rapid in action than all new charcoal. Charcoal made from hard woods as oak is preferred to that prepared from the softer kinds.

After the pots have been charged, the manhole is bricked up, and the trial bars luted round with clay. The fire is lit, and the temperature gradually raised, until in about forty-eight hours the heat required for conversion is reached, at which temperature the furnace is maintained during from seven to ten days. The difference in the length of time is that due to the degree of carburisation required ; the harder the temper wanted, the longer the period. Spring temper requires the least, and welding temper the longer period, shear steel being intermediate. Time, however, is not an absolute condition, and therefore the trial bars are withdrawn at frequent intervals to study the progress of the cementation in them by the aspect of their fracture. The "sap" of a bar is its core of non-converted, scarcely affected bar iron in the "spring heat," or No. 1 bars. But as the conversion proceeds, the core is reduced, until in No. 6, or "melting heat," there is no iron left, but steel throughout. In the intermediate grades the one merges into the other gradually. If there is a sharp line of division between the iron and steel it indicates that the conversion is proceeding at a too rapid rate. When the proper temper is obtained, the fire is allowed to burn down, until in the course of a few days the furnace is cool enough for a man to enter, and draw the heat.

The bars of blister steel show a rough surface, with blisters ranging from the size of a pea to an inch in diameter, and with a crystalline fracture. The carbon has been absorbed, the bars now showing a content of about 1·5 per cent. more or

less, and the proportion of sulphur in the iron has been reduced by about one-half.

The bars are not homogeneous, and they are therefore broken up and graded by the appearance of their fractured surfaces. Faulty bars are those which have been slightly fused on the surface (glazed) and those which have become oxidised by access of air (aired bars).

Although there is an infinite gradation in the qualities of the broken bars, the trade gives definite names to six of them as follows :—

	Per cent. of Carbon.
No. 1. Spring Heat	$\frac{1}{2}$
No. 2. Country Heat	$\frac{5}{6}$
No. 3. Single Shear Heat	$\frac{3}{4}$
No. 4. Double Shear Heat	1
No. 5. Steel through Heat	$1\frac{1}{4}$
No. 6. Melting Heat	$1\frac{1}{2}$

If it is required to make blister steel with more than about 1·4 per cent. of carbon it has to be converted twice over, and it is suggested that in the interval it may part with some of its occluded carbonic acid to make room for a further occlusion of carbonic oxide.

Dannemora iron is that from which the best steel is made. Mr Seebohm has stated as a fact beyond the possibility of a doubt that "it is quite possible to make a comparatively low-priced steel, which shall show precisely the same chemical analysis as the best crucible cast steel; nevertheless it is found by practical experience to be inferior in quality." This explains why high-priced Dannemora iron is purchased by the Sheffield manufacturers.

The theory of cementation, is that at the high temperature—a white heat—the metal being capable of occluding many times its own bulk of gas: it takes up carbonic oxide, formed by the union of the charcoal with the air in the converting pot. The iron takes up a portion of the carbon, reducing the gas to carbonic acid.

Cementation for Annealing.—The process of annealing for the production of malleable cast iron is one of cementation. The articles under treatment being of a particular chemical composition, are subjected to long continued heat in the presence of oxygen, by which the castings become decarbonised and softened, taking the properties of malleable metal. This therefore is the reverse of the converting process of the steel maker. The two resemble each other only in the fact that a cementing material is essential, and both depend for results upon the occlusion of gases by the iron at a white heat.

Reaumur is believed to have been the first to show (1722) that cast iron became softened when embedded in red oxide of iron at a high temperature. The commercial method was due to Samuel Lucas (1804), and he described the action precisely. The castings were "to be put into a steel converting, or other proper furnace, together with a suitable quantity of ironstone, iron ore, some of the metallic oxides, lime, or any combination of these (previously reduced into powder, or small pieces), or with any other substance capable of combining with, or absorbing the carbon of the crude iron. A degree of heat is then to be applied, so intense as to effect a union of the carbon of the cast iron with the substance made use of, and continued during so long a time as shall be found necessary to make the cast iron either partially or perfectly malleable, according to the purposes for which it may be wanted,"—with other details of the precautions to be observed.

The essential feature therefore is the abstraction of carbon by the action of a cementing substance. In England this is usually hematite ore, ground into particles of about the size of a pea; or hammer scales, both rich in iron oxides. The proof that the oxygen is the active agent is seen in the fact that the hematite ore becomes spent, being reduced more or less to a metallic state by the loss of its oxygen, and hammer scales have to be re-rusted if they have to be used again.

Yet so long as oxygen is allowed access, it need not be present in the cementing agent. It must get there, otherwise the carbon could not be oxidised to carbonic oxide. But sand and lime have been used, and sand mixed with ferrocyanide of potassium, and black oxide of manganese. These inert materials support the castings, and prevent the too rapid action of the atmosphere. But it is unnecessary to use these when the powerful oxidising agents hematite and mill scale are available. The chemical composition and the methods of manufacture

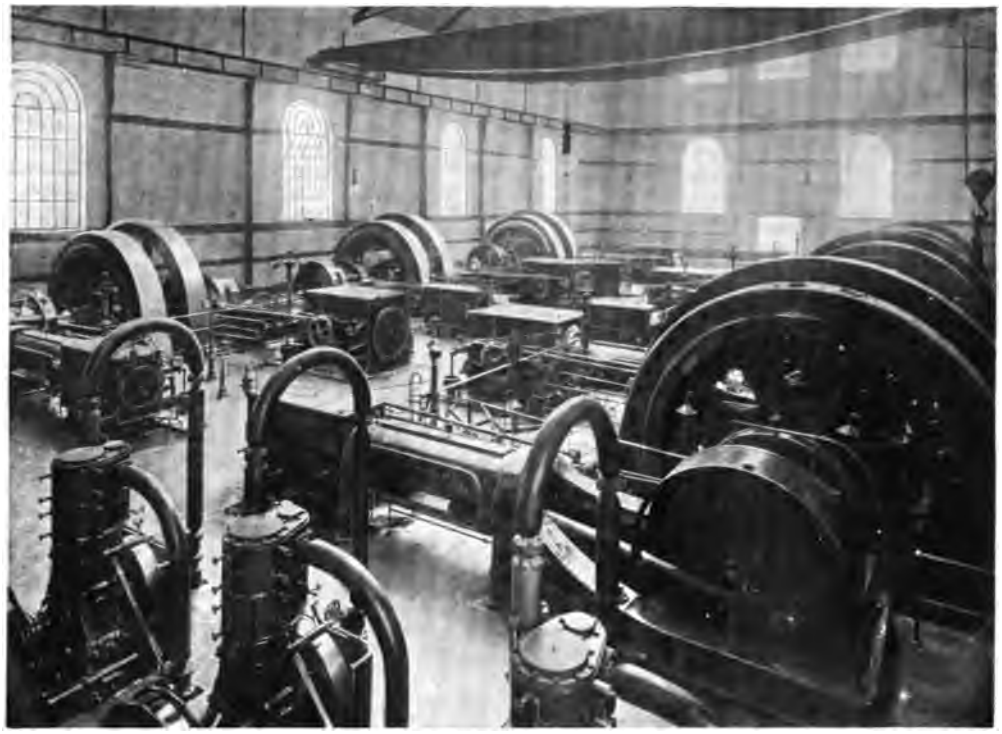


Fig. 138.—Power Station, Central London Railway. (Equipped by the British Thomson-Houston Co., Ltd.)



Fig. 139.—Power House at the Rugby Works of the British Thomson-Houston Co., Ltd.

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of **Malleable Iron Castings** will be found treated under that head.

The carbonising of armour plate is a cementation process. *See* **Carburising Furnace.**

Cementite.—A constituent of steel corresponding with the formula Fe_3C. It is hard, and stands in relief when steel is polished with fine rouge or parchment placed on a soft support. It remains bright after the polished section of steel is treated by an iodine solution, or an infusion of liquorice. It seldom occurs in low carbon steel.

Cements.—Substances, which being applied in a plastic state to the objects to be united, harden subsequently. The hardening may be due to chemical action, or more often to the sticky character of the uniting substances. When the uniting medium is metallic the term solder is applied. The recipes given for cements often fail to act, not through any fault of the medium, but through neglect of obvious precautions. Among these are the lack of proper preparation of the jointing faces. The lack of continuous contact of these is a common cause of failure. Another is the presence of dirt, grease, scale, red rust. Cold will prevent adhesion in many cases, so will the neglect to rub out superfluous cement from a joint. On the other hand, a considerable body of cement is sometimes required, only then it is not a means of union but of caulking, as in stemmed joints in tank plates and in pipes. In chemical setting cements due proportions of ingredients must often be observed as in rust cements, or the non-hydrated condition as in plaster of paris. Some of the most useful cements will be given under their appropriate heads.

Centigrade.—*See* **Thermometer.**

Centigramme.—A measure of weight, equal to the hundredth part of a gramme. *See* **Metric System,** and **Gramme.**

Centilitre.—A measure of capacity, equal to the hundredth part of a litre. *See* **Metric System,** and **Litre.**

Centimetre.—A measure of length, equal to the hundredth part of a metre. *See* **Metric System,** and **Metre.**

Central Stations (Electric). — Central stations for generating electricity are arranged as far as possible in the centre of the area they are to supply, whether they are intended to furnish current for lighting, or for power. On the other hand they must be situated where the electricity can be most economically generated, when all charges have been taken into account. In large manufacturing towns, and in London, New York, Berlin, and other cities, the sites available in central positions are so expensive that the rent or interest on the purchase, and the taxes, add very seriously to the cost of generation, and hence it is very common for generating stations to be fixed on the outskirts of towns. Other requirements are, a convenient supply of fuel and water. In the centres of large towns both of these are costly, as coal has often to be hauled by carts to the station, and the only available supply of water is that of the town.

On the other hand, the flexibility of electricity enables the central station to be placed a long way from the centre, because the electricity can be generated at a high pressure, transmitted at that pressure to the points of consumption, and there transformed down to the pressure required by the lamps, or motors. The ideal position for a generating station is that which has been obtained by some of the Electrical Power Companies, close to a colliery, and close to a fairly large river. The coal is brought straight to the station in the colliery wagons, and the water for condensing is taken from the river and returned to it again. The next best position is on the banks of a river, such as the Thames, where barges carrying coal can come right to the works, and water is again available in large quantities. There is yet another class of central stations, those in places like California, where fuel of any kind is very dear, as they are so far from the coal-fields, and where the energy of the fall of a river is employed, the electricity being carried to the point of consumption.

The central generating station has several complete units, each consisting of a generator, with its driving engine, its boiler, where steam is used, its condenser, feed pumps, and other accessories. The great majority of central stations are worked by steam engines, a fairly large number by water power, and a few by gas. In all cases now the steam, water, or

gas engine in the modern central station is directly connected to the electric generator. Steam engines of the reciprocating type are employed, and also turbines, the latter being more and more used as the size of the units increase. The reciprocating engines employed are either of the slowly revolving type, with long strokes, or of the quickly revolving type, with short strokes; the latter having been more and more employed as central stations have developed. Gas engines used for generating stations are supplied either with producer gas, made at the works, or with the gas from blast furnaces (*see* **Blast Furnace Gas Engine**), or coke ovens. Suction gas producers will probably be used more and more as time goes on. The engine, with its producer and accessories, makes a complete unit, just as the engine with its boiler and accessories does. The sizes of the units vary very considerably, and depend upon the work to be done during the time of light load.

The advent of the power generating station is largely due to the fact that wherever power is employed in driving machinery, there is always a user factor. All the machinery is not running at the same time. The user factor varies with different industries, and may be anywhere from 30 per cent. to 60 per cent. of the total possible load. In the central station the power not required for one firm or one machine is used by another automatically. But in nearly all industries, and under nearly all circumstances there is some part of the day during which there is very little demand for current, in proportion to that in the other parts of the day, and the individual units in a central station depend upon the electricity required during this period. In many cases one unit furnishes current during this period, a second being always ready to come into service if required. The units into which the generation is divided will usually be multiples of the unit which performs the work during the period of light load. At the Lot's Road Station of the Underground Electric Railways Co. of London, Ltd., the units are of 8,000 HP., each consisting of a steam turbine of that capacity, with its generator, its boilers, condenser, and all accessories. In central stations for the lighting of small towns the units may be as low as 50 HP. each. With the development of the use of electricity for power, the size of the units is increasing.

The electricity generators may be of the continuous current, or the alternating current type. The tendency is for comparatively small stations, supplying small areas, to have continuous current machines, while larger stations, supplying large areas, have alternators. A good many of the earlier lighting stations were fitted with single-phase alternators, but the tendency now is to use three-phase alternators. This again will probably be changed if the single-phase motor establishes itself for railway work. Central stations for tramway work necessarily have continuous current machines, unless the area covered is very large, in which case three-phase machines are employed, in connection with sub-stations. In some central stations there are two complete sets of plant; continuous current, intended for the near neighbourhood, and three-phase for the more distant.

In a good many stations there are additions made to the plant, in consequence of the use of accumulators, and in connection with the three-wire system. Small stations are enabled to shut down during the night by charging accumulators during the day, and supplying the service from them during the night. Some large stations have also adopted accumulators to absorb the temporarily unused power throughout the day, employing it to help the other machines during the times of very heavy load. For charging the accumulators, "boosters" are employed, which convert the pressure of the service to that required to charge the accumulators, and the "booster" allows the current from the accumulators at any moment to be used for helping the ordinary machines by reconverting the pressure to that of the service. For the three-wire system "balancers" are required. They are smaller machines, two being connected together, whose office is to transport the energy from one side of the three-wire system, where the demand is low at any period, to the other side where the demand is higher. The balancer is sometimes electrically driven, the transference of energy from one leg of the system to the other being then automatic, and sometimes it is steam driven, when the engineer arranges

the output according to the requirements of the service. With steam-driven balancers the balancing set is often used as a generator, during light load, or to assist the regular generators.

All the generators, of whatever type, are connected to the switchboard, and all the "feeder" cables, which carry the current to the supply service, are also brought to the switchboard. The switchboard itself consists of a number of panels of marble or enamelled slate, mounted on a skeleton framework of steel. On the different panels are mounted switches and fuses for connecting the different generators to the "bus bars," instruments showing the current and pressure each generator is delivering, and apparatus for regulating the pressure at which it is working. On other panels are switches and fuses for connecting the different "feeders" to the "bus bars" and instruments showing the current they are taking. Other panels carry switches, measuring instruments, and controlling apparatus for the balancers, the boosters, &c. Mounted on the switchboard, usually at the back, are the "bus bars" referred to above, two, three, or more substantial copper bars, according to the system in use, with connections for the switches of the generators, and the feeders. The "bus bar" system is almost universally employed in central stations now. All current generated comes to the bus bars, all current required is taken from them. The pressure at the bus bars is always the same at any instant, and it is maintained at fixed pressures at different parts of the day. The great object attained is, that the pressure delivered to the service is the same at any instant, and remains the same unless a change is deliberately made. It enables the engineer in charge also to provide for his load as it comes on, by connecting successive generators to the bus bars, and it enables him to distribute the load between different generators at will, by the aid of the regulating apparatus attached to each. There is no break in the continuity of the service, as the load comes on, or goes off, as there is where what is called the "independent" system is employed. In the independent system, there are no bus bars. Each feeder is switched on to a particular machine, and when that machine has more than it can conveniently furnish it is switched on to another, the reverse operation being gone through as the load comes off.

The usual arrangement of a central station is this:—There is a large brick-built building, lighted from the roof in some cases, and the sides in others, divided into two portions. In one part the boilers, condensers, pumps, &c., are placed. In the other compartment the engines and dynamos are fixed. A wall usually divides the two, the steam pipes being carried sometimes through it, and sometimes under it. The switchboard usually occupies a gallery in a convenient position, within sight of the engine driver.

With the large increase in the size of the central stations, these arrangements are being modified. In the Lot's Road Station, for instance, the boilers are at a higher level than the steam turbines. With the high pressures that are coming more and more into use also, the switchboard is divided. The actual work of switching is performed by electric motors, or solenoid electro-magnets, which are put in operation by small switches on the working switchboard, the high-pressure board being fixed well out of the way. This is called "remote control." The switchboard attendant only operates switches which make and break currents of low pressure. Figs. 138 to 141, Plates X. and XI., illustrate various Central Station equipments.

Centre Casting.—It is in some cases found desirable to pour a mould at the centre, and allow the metal to distribute itself radially to circumference, instead of casting at the outer edges. The advantage lies in the more rapid distribution of the metal, while hot; and consequent lessening of risk of imperfect filling, and of cold shuts.

The class of work in which this is found suitable is that where there is a boss or central portion with a greater mass of metal than that elsewhere. The iron, &c., being poured into the thick part, remains hot long enough to run into and fill the thinner parts surrounding. But if poured into the latter first it would have a longer distance to traverse, and might be getting cold before it could fill up the boss and

reach the thinner parts of the mould beyond. This method is of greater value the larger the dimensions of castings, and the greater the disproportion between thicknesses. The alternative generally would be to pour at opposite sides of the mould at once.

When pouring at the centre through a boss, a good plan is, instead of pouring on the boss, to form the ingate and the runners in the centre core, rammed in a box, and direct the runners straight into the ribs of the casting. The metal then takes an easy course without beating up against sand.

Centre casting also relates to the method of pouring steel ingots in a circle with a centre casting crane.

Centre Casting Crane.—Denotes a form of crane used in Bessemer plants, in which the ingot moulds are arranged circularly in a group around the crane, which has a horizontal jib along which the casting ladle is traversed, and a rise and fall motion, and a slewing one. It may be self supporting, or have a top centre in addition to the bottom one.

Centre Gauge.—A small tool of sheet steel having several vee notches of various sizes, and one vee end, used for the purpose of testing screw-cutting tools for angle, and also setting them squarely on the slide rest. The angles are made to 55° for the Whitworth thread, and 60° for the Sellers (U.S.) and the International systems. Graduations are usually located on the faces of the gauge, to add to its usefulness.

Centre Grinder.—In order to keep the point centres of lathes in good shape, and running truly, centre grinders are commonly used, carried on the slide rest. The practice of turning up the centres is unsatisfactory, and is of course out of the question when they are hardened as is now usual. The grinders consist of a little frame carrying the spindle, and grinding wheel, the latter being moved to and fro across the centre, at the proper angle, while the headstock spindle is running. Various means are adopted to drive the wheel: as by hand, through spur reduction gears, for getting a suitably high speed; by friction drive from the headstock cone, revolving a rubber wheel, connected to the wheel spindle; by belt drive from the rim of the face plate, actuating two other pulleys, thence to the spindle of the wheel; or by belt or cord from overhead. Some small electrically-driven types, with the motor on the grinding spindle are also used with success.

A cylindrical grinding machine, like a lathe, has point centres, but these can be trued up by the wheel of the machine without the need of any special attachment.

Centre of Buoyancy, or centre of displacement. When a solid is placed in a liquid it is immediately acted on by two forces, (*a*) the downward force of gravity tending to sink the solid, (*b*) the upward pressure of the water. When the body floats, either partly or entirely immersed, in equilibrium, these two forces must balance each other, and as stated under **Buoyancy** the weight of the displaced liquid must equal the weight of the body. Now the weight of the body is considered to act vertically downwards through its centre of gravity; and the upward pressure of the liquid (equal to the weight of displaced fluid) acts through the centre of gravity of the displaced liquid. This latter point is the "centre of buoyancy" and so may be defined as the point at which the resultant of the upward fluid pressure acts. If the body floats at rest, the line joining the centres of gravity of the body and displaced liquid (called the axis of equilibrium) must be vertical. Otherwise the upward pressure of the liquid would produce a rotatory motion in the body.

If the equilibrium of a floating body be disturbed, as in the case of a ship in a rough sea, the centre of buoyancy is shifted with every lurch of the vessel, and its new position is of great importance in determining another point on whose relative position depends the power of a ship to right itself. This point is called the **Metacentre.**

Centre of Force.—A term sometimes used to denote the **Centre of Pressure.**

Centre of Gravity.—In any body, is that point at which the whole weight of the body may be supposed to act. We may consider the force of gravity as acting along a series of lines joining each particle of a body with the centre of the earth. As a distance of some 4,000 miles



Fig. 140.—Westinghouse Generators, Turbine Driven, 5,000 HP. each. (Niagara Falls Power Co., Niagara.)



Fig. 141.—Westinghouse Generators, 1,500 K.W., Direct Connected to Westinghouse Steam Engines. (The Metropolitan Electric Supply Co., Willesden, London, W.)

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separates these points, such a series of lines would be practically parallel, and so the centre of gravity is the point through which the resultant of this system of parallel forces passes. In problems concerning the equilibrium of bodies, their weight is considered to be concentrated at their centre of gravity, and so it is necessary to find this point.

In certain symmetrical figures the c.g. coincides with the centre of *mass*. In a uniform *rod* the c.g. is situated at the middle of its length; in a *square*, *rectangle*, *rhombus*, or *rhomboid*, the c.g. is at the intersection of the diagonals; the c.g. of a *circle* or *regular polygon* lies at the centre. Similarly in solid figures, such as a *sphere*, *cube*, and *ellipsoid*, the c.g. lies at the centre of mass.

The c.g. of a *triangle* lies on the line which joins the middle point of any side to the opposite angle and at a distance from that angle equal to two-thirds of the bisecting line. In a *solid cone* or *pyramid* the c.g. is in the axis drawn from the apex to the c.g. of the base, and at a distance from the base equal to one-fourth of the length of the axis; in a *hollow cone* or *pyramid* the distance is at one-third of the axis. In a *solid hemisphere* the c.g. lies on the radius, and at a distance from the centre of the sphere equal to three-eighths of the radius; in a *hollow hemisphere*, at the middle point of the radius.

The c.g. of any flat body of irregular outline, such as a plate of metal, may be found experimentally. Suspend the plate, Fig. 142, 1, by attaching a cord to it at the point A. The weight of the plate and the pull of the cord then equal each other, and when the plate is at rest, they act in the same vertical line AC, which may then be marked with a piece of chalk. The c.g. lies therefore somewhere in AC. Next support the plate from some other point, say at B. The c.g. again lies in the vertical line BD. Chalk this, and the point G where the two lines intersect is the c.g. of the plate.

A body is then in equilibrium when its c.g. is vertically under, or above, the point of support, and in the case of a body resting on a plane surface, it will stand or fall according as the vertical line drawn from its c.g. falls within or without the base. In Fig. 142, 2, A, A will stand, B, B will topple over. When a body is not supported by a solid base as in many machines, carts, &c., the base is the area enclosed by a line drawn round the points of support.

A body may be in (1) stable, (2) unstable, or (3) neutral equilibrium, according to whether, when disturbed, (1) it returns to its original position, (2) tends to move still further from its original position, or (3) remains in equilibrium in the new position. An example of the first is seen in a pendulum hanging at rest, or an egg

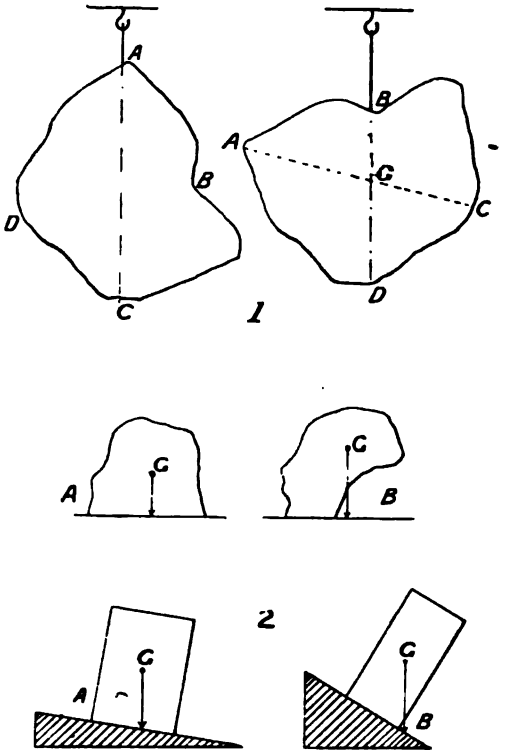


Fig. 142.—Centre of Gravity.

on its long side. When disturbed, these things finally return to their first position. But if by getting the c.g. of an egg vertically over its end, we can support it on that end, we have an example of unstable equilibrium, for the least disturbance will move it further from this position of equilibrium. The same thing is seen when a cone is balanced on its apex. A round ruler resting on its long side, or a marble, is in neutral or indifferent equilibrium, for when disturbed each remains at rest in the new position.

Formulæ for the working of problems dealing with the acceleration of gravity are given under **Acceleration.** *See also* **Balance Crane.**

Centre of Oscillation.—In any suspended body, like a pendulum, particles at different distances from the point of suspension move at different rates, those furthest from the point of suspension moving fastest. The centre of oscillation is a point in the body so situated that if all the particles could be concentrated at it, the body would continue to move with the same angular velocity and the same number of oscillations. The centre of oscillation always lies further from the point of suspension than does the centre of gravity.

Centre of Percussion.—If a body which is free to rotate about an axis is struck, so that the blow does not produce any pressure on the axis, then the point at which the direction of the blow cuts the plane containing the axis and the centre of gravity of the body, is the centre of percussion. It is also the centre of oscillation.

Centre of Pressure, or centre of force, is the point in a surface at which the whole amount of pressure might be applied and yet produce the same result as when it is distributed. If a plane surface be immersed in a liquid the pressure of the liquid acts perpendicularly to the surface of the plane. This pressure may be regarded as constituting a system of parallel pressures whose resultant is equal to their sum. If this resultant pressure were applied to the point in the plane surface called the centre of pressure its effect would be the same as when the pressure is distributed.

The determination of the centre of pressure is sometimes a matter of considerable difficulty, but yet is of great importance in calculating the necessary strength of retaining walls for water, earth, &c., &c. On a horizontal area the centre of pressure is at the centre of gravity, but in an oblique or vertical surface the pressure increases with depth, and the centre of pressure is then below the centre of gravity. In plane surfaces of uniform width the centre of pressure is situated at two-thirds of the depth below the water level.

Centre Plates. — Small plates used by pattern-makers for turning work in halves between the lathe centres. Their function is to hold the halves together, and provide centre holes for the lathe centres to fit into. They are used in pairs, one plate having a slot to take the fork centre, and the other a countersunk hole for the dead centre, Fig. 143. The plates are seldom more than from 2 in. to 3 in. square, by about ¼ in. thick. They have a hole at each corner for screwing or nailing them to the work. Small plates have only two holes, one for each half of the wood. Other plates for small work are not screwed on at all, but provided with projecting points on their inner faces, Fig. 143, A, which are sufficient to keep them in place and hold the wood together, and when the work is screwed up between centres there is no risk of their coming off.

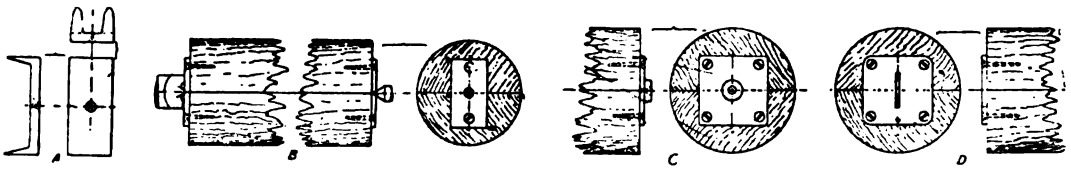


Fig. 143.—Centre Plates.

A. Dog form, used without screws. *B.* Plates held with two screws. *C, D.* Ditto, with four screws.

In putting on centre plates, care must, of course, be taken to get them central on the joint, otherwise the joint will be thrown more or less out of centre, and the halves of the turned pattern will not be equal. The use of centre plates is an alternative to other methods of holding halved work together in the lathe, but in heavy turning where security is important, and the hold of the lathe centres in soft wood unreliable, they are nearly always employed in addition to other methods.

Centre Punch, or Prick Punch.—This is in constant use in all classes of metal working where an ordinary scribed line would be unsuitable for working by, or liable to oblitera-

tion. Centre-pops are made to start a drill or punch by, to mark the course of lines and circles, to set dividers in for striking circles, &c. The common form, Fig. 144, A, is either plain, or knurled on the body, and is made of various sizes for heavy and fine work. B is employed for marking through plates, the punch being turned to fit the hole already existing, so that accurate matching is insured. The spacing centre punch C is useful for popping a series of dots at uniform distances apart, such as for cutting out a plate or die by drilling a row of contiguous holes. The spacing point *a* slides in the end of a pivoted rod or strip *b*, attached by a screw to the side of the punch *c*, and adjustable to and from the latter by a screw and

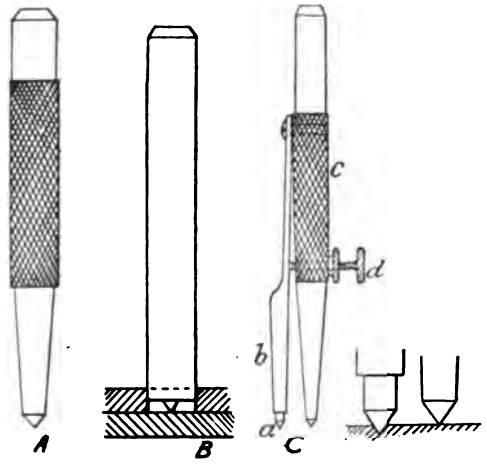


Fig. 144.—Centre Punches.

lock-nut *d*. The end *a* slides in its holder *b* against a spiral spring, this being necessary, because if both points were rigid and level with each other, the punch would have to lean over as one point was inserted in the last pop made, and the pitching would be inaccurate. With the spring plunger, the effect is as seen in the supplementary view alongside the punch, the loose point lying below the level of the work face.

A recent Brown & Sharpe centre punch is designed to avoid the use of a hammer, so leaving the worker's hand free. A strong spring is contained in the hollow body of the punch, and as the head of the latter is depressed the spring is compressed until at a certain position it kicks loose, and imparts a smart blow to the end of the punch plunger sliding in the body. The tool may be run along a line very rapidly, and with more precise results than the usual punch, driven by a separate hammer.

Centres.—This applies to the headstock and poppet centres of a lathe; the latter kind are treated under **Back Centre,** and the remarks there apply equally well to the running centre, except that the latter is only made in the two forms of ordinary pointed, and the blunt, of larger diameter, for tubes. The running centre is often recommended to be left soft, only the back centre being hardened, but this is not good practice, because although the revolving one endures no friction, it is gradually pulled out of shape by the pressure of the work, and hardening delays this distortion. The centres in work are shown under **Centring.**

Centres—Centre Lines.—In nearly all mechanical drawing, and in the setting out of dimensions in the shops, the centre and centre line form the basis from which measurements are taken. An exception is gauging, or setting off from a face or line already in existence. Diameters, widths, distances, thicknesses, are mostly obtained from centres, and centre lines.

The advantage of this is that accuracy is more readily secured than as though dimensions were taken from bounding lines indiscriminately, which would involve adding and subtracting, with much waste of time. In fact the advantages seem self-evident without observations thereon.

Centres on mechanical drawings are sometimes indicated by a small circumscribing circle, to save trouble in their location for reference. Centre lines are drawn in full lines in pencil, and on shop drawing boards. But in finished drawings they are indicated by dotted lines, or by chain dotting (dash and dot) or by full blue, or red lines.

The term centre has many other specific applications. A rather important distinction, because it is an aid to the analysis of mechanical movements, is that between fixed or permanent, and instantaneous centres. The first signifies the centre as commonly understood, that of the axis of a rotating body, as a shaft or wheel (spheric motion). The second is that of a body in transla-

tion, whether in an irregular (non-plane) path, or in a straight line (plane). At any instant the body is moving in relation to a point which may be determined, being at a finite distance in the case of any curvilinear motion, but at infinity for a movement on a straight line. But it differs from a permanent centre in being a centre of movement for an instant only, changing its place constantly in space. For examples, *see* **Closed Chains.**

There are also a number of mechanical centres in statical and dynamical problems.

Centre Square.—An instrument employed both by wood and metal workers for finding the centres from which curves have been struck. It can only be properly employed against the edges of work, and is not suitable for drawings or flat surfaces. It is made in several different forms, but the principle is the same in all, being simply a tee square with its head so modified that when used against a curved edge the blade always goes radially to the centre of the curve. An ordinary tee square can be used as a centre square by gauging a line on the head or stock at right angles with the blade, and boring two holes at an equal distance on each side of the edge of the blade near each end of the stock. Two pins are made to fit these holes, and to project half an inch or so on the under side of the tee square. To use it as a centre square the sides of these pins form a bearing surface instead of the straight-edge of the stock. The diameter of the pins is immaterial.

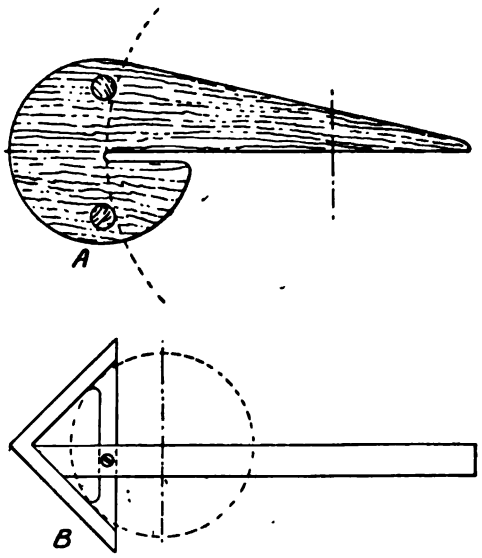


Fig. 145.—Centre Squares.

A small centre square used by wood-workers is made of a single piece of thin wood with two pins inserted, Fig. 145, A, and the wood is cut to a shape which affords sufficient body for the pins and provides a straight-edge down to the centre. The pins, inserted in the square, bear against the edge of the curve, and the long straight-edge of the instrument cuts across the centre of the work; a short line is scribed, and the square shifted around to a fresh position, another line marked, and so on until four or so have been done. The mean of these gives the centre. A different pattern B is made of steel; and a vee head, arranged in the form of two edges at right angles to each other and at 45° to the blade, forms the periphery guide (as indicated by the dotted circle). Graduations are often placed on the long stem or straight-edge.

These two edges or surfaces are suitable only for embracing convex curves, and are limited also to those small enough to bear within the edges of the right angle. This type of centre square, however, is more commonly employed than the other, and is made in two forms. In one it is complete in itself, with stock and blade permanently attached to each other; and in the other the stock is separate, and made so that it may be attached to an ordinary rule or straight-edge.

Centre Tester.—*See* **Indicator.**

Centre Weighted Governor.—An ordinary revolving pendulum or Watt governor, Fig. 146, A, consists of a pair of rods pivoted on a vertical rotating spindle, and each carrying a heavy ball at its extremity. The time of a half rotation of 180° is the same as that of a single swing of a common pendulum of the same length, and if made to rotate more quickly, the balls must swing out and rise nearer to the point of suspension, thus shortening the pendulum.

The time of rotation is:—

$$t = 2\pi\sqrt{\frac{a}{g}}$$

where a is the vertical height in feet from

the point of suspension to the centre of the heavy ball, or more correctly to the centre of gravity of the ball and rod, g = gravity or 32·2.

In order to increase the power of a governor and its sensitiveness, the speed must be increased. To enable this to be done, a central weight is placed to slide freely on the governor spindle, and it is connected by a pair of links to the ball arms, Fig. 146, B. Then if W = weight of one ball; W_1 = half weight of central weight, the height H of a loaded governor will be $H = a \times \frac{W + W_1}{W}$ or $H = \left(\frac{W + W_1}{W}\right) \frac{35160}{N^2}$ ins.

The square of the number of revolutions enters into the expression, and since there is a considerable difference between N^2 and $(N - x)^2$ even when x is a small fraction of N, it follows that a small change in the speed of rotation will represent a considerable change of height H. The amplitude of movement or the tendency to move is thus considerable, and the weighted governor will therefore control an engine better and more promptly than will a common governor.

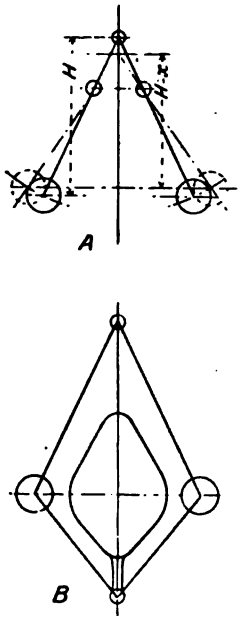


Fig. 146.—Centre Weighted Governor.

The load of the early loaded or Porter governor was always a weight threaded on the central spindle, but a spring may also be employed. As the governor rises and the revolving arms approach the horizontal position more closely the lifting power of the governor becomes less, and the height will vary less with a given speed difference at different positions. With a spring load this is accentuated, and these facts must be taken into account in the design of a governor and the method of connecting it to the engine, because in order that a governor shall not hunt, the movement of the governor, for a given change of speed due to change of load, must never be so great as will admit steam sufficient to bring back the engine to its original speed. In other words, the governor must lag behind the engine by some small amount. This means that a lightly loaded engine must always run faster than when on heavy load. A governor which endeavours to reverse this order produces hunting, and the condition is approached by any too sensitive governor. Hence the use of dashpots to render the governor more sluggish in movement without preventing its ultimate attainment of its true altitude. The action of the dashpot is to check the effect of momentum in carrying the governor beyond the point to which it has moved perhaps somewhat rapidly.

Centrifugal, or Hydro-Extractor.—Employed for the extraction of liquids from semi-solid matters, or bodies containing moisture. The principle is that of high-speed rotation of the substances in a vessel, which throws off by centrifugal force the easily separated fluids outwards, through perforations or meshing. The application is to sugar, and various chemicals, as well as for the rapid drying of various objects.

The mechanism of a typical machine is seen in Fig. 147, the principal point of interest being the hanging and rotation of the spindle. In the illustration, A is the frame, supporting a head casting B. The horizontal shaft has fast and loose pulleys, C, C, actuating a friction clutch driving the large pulley D. The belt from this passes over guide pulleys E, to the pulley F, the latter having an extended portion to receive a brake band for rapid stopping. F drives the main outer spindle G, running on a fixed one H, which is held in the bearing at the top of the frame. Another inner and rotating spindle J is pinned to G, and runs inside H; the bottom bush is seen just above the letter J. J is hung upon a ball-race at the top, and indiarubber buffers below (marked black) absorb vibration. At the bottom of the spindle G the tapered end receives a casting K to which the perforated cage or basket is fastened. The extracted liquid is thrown into the case M, provided with an outlet pipe at the bottom.

Similar machines are also fitted for drive by steam engine, or by motor, placed on the base, instead of the pulleys, C, C. Various modifica-

tions are made in design to suit work of different characters.

Centrifugals of small size are used in machine shops to extract the oil from turnings, cuttings, and pieces produced on screw machines, milling machines, &c., the lubricant being then filtered, and used over again. This is essential because of the cost of the lubricant, which cannot be wasted, and because the products would not be clean enough otherwise. These machines are mounted on a base, and pulleys carried thereon drive to a pulley on the vertical shaft. Figs. 148, 149, 150, Plate XII., illustrate various centrifugals.

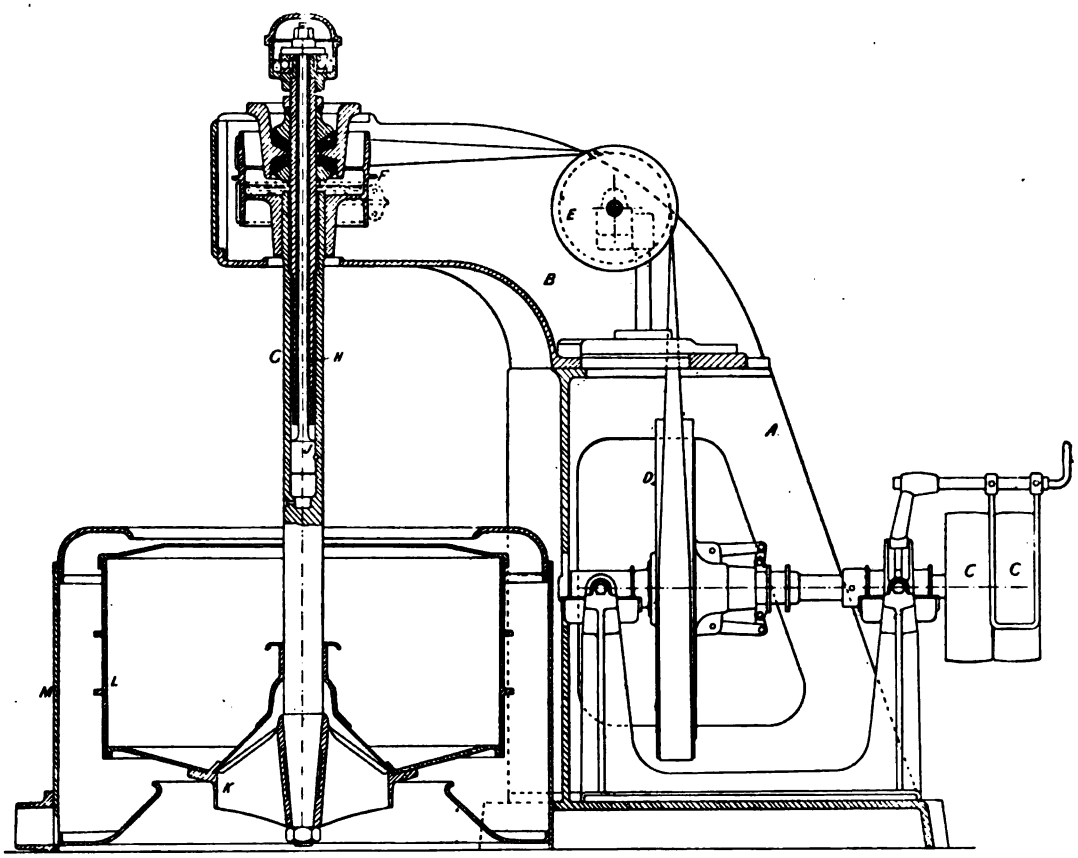


Fig. 147.—Centrifugal. (Pott, Cassels, & Williamson.)

Centrifugal Casting.—A device that has been tried at intervals with the object of producing sound steel castings, notably at Crewe, where Mr Webb cast the steel wheels for locomotives and rolling stock in this way.

Hoops have been cast for tyres in this way, but they were often ruptured by the centrifugal force. Several other attempts have been made since the first patent by Eckhardt in 1809.

The principle underlying the method is based on the different specific gravities of metal, and of gases and slag. The effect of rapid rotation is to drive the heavier bodies towards the circumference, leaving the lighter ones to flow up into a feeder head at the centre. The force is proportional to the square of the speed of rotation, and this, in addition to the natural tendency of the heavier to sink and the lighter to rise, should be expected to effect a separation of the sound metal from the gases and scoriæ. But practical difficulties have prevented the theoretical action from being accomplished in a satisfactory manner. Excellent results are obtained by casting gun-metal pump barrels

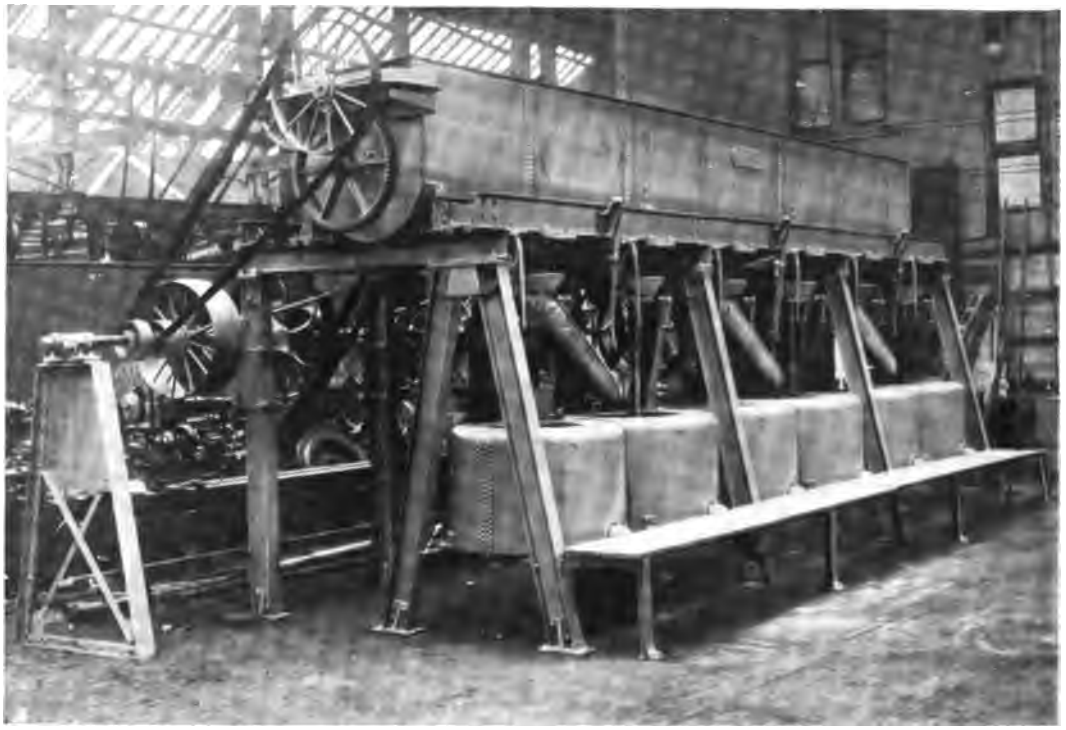


Fig. 148.—Set of Six Centrifugals, with Overhead Mixer for Drying Sugar.
(Pott, Cassels, & Williamson.)



Fig. 149.—Set of Four Centrifugals, with Sugar Breaker, and Mixer for Drying Sugar.
(Pott, Cassels, & Williamson.)



Fig. 150.—Electrically Driven Oil Separator.
(Manlove, Alliott, & Co., Ltd.)

To face page 192.

centrifugally, an absolute freedom from specks or blown holes being secured.

Centrifugal Force (Lat. *centrum*, centre, and *fugio*, to flee from), defined in accordance with its etymological origin, would mean the force which drives a revolving body away from the centre of its orbit. There is, of course, no such force, the tendency of any body so revolving being to continue its motion in a straight line, *i.e.*, to fly off at a tangent to the circle, and by centrifugal force we understand this resistance to motion in a curved path. To compel the body to move in a circle, force must be applied perpendicularly to the tangent of the circle. This latter force compelling the body to travel in a curved path is the centripetal force (Lat. *centrum*, and *peto*, to seek). Centrifugal force obviously increases with velocity.

The acceleration directed towards the centre of the circle is found by

$$\text{Acceleration} = \frac{V^2}{R},$$

where V = velocity in ft. per sec.; R = radius of the circle in ft. The centrifugal force is found by multiplying together the acceleration and the mass of the body, so that if M = mass, and G = acceleration of gravity, 32·2 feet per sec., then—

$$\text{Centrifugal force} = \frac{MV^2}{GR}.$$

When N, the number of revolutions per minute, is given,

$$\text{Centrifugal force} = M\frac{\pi^2 RN^2}{900G},$$

this formula being obtained from the previous one by substitution of the value of V which

$$= \frac{2\pi R \times N}{60}, \text{ and } V^2 = \frac{4\pi^2 R^2 N}{60 \times 60}.$$

Hence, centrifugal force

$$= M\frac{4\pi^2 R^2 N^2}{3600GR} = M\frac{\pi^2 RN^2}{900G}$$

(dividing numerator and denominator by 4R).

Wherever in engineering, revolving masses are concerned, centrifugal force has to be considered and in some cases its disastrous effects neutralised. In the design of a flywheel the tensile strength of its rim must be borne in mind, the bursting of flywheels and grindstones when revolving at high speeds being due to centrifugal force. Generally the rim itself is made sufficiently strong to resist the tension without assistance from the arms. Centrifugal force again causes the balls to open out in the governor of a steam engine when the speed increases. On railway curves the outer rail is always more worn than the inner rail, as the former has to bear the pressure required to keep the wheels from running off at a tangent to the curve. And, as in any question concerning this force, it increases with the speed of the body and the sharpness of the curve. The form acquired by the earth in its pre-solid days—that of an oblate spheroid, or a sphere flattened at the poles—is due to centrifugal force, for as it rotated on its axis, the matter composing it tended to move out at right angles to the axis, just as increase of speed causes the balls of a governor to move outwards.

Centrifugal force is utilised in various machines. In the centrifugal pump a rotating fan causes the water to be drawn in and delivered in a regular stream. Several machines are used for the drying of yarn, cloth, sugar, &c., by enclosing the wet material in a hollow, perforated, rotating cylinder. *See* **Centrifugal Separator.** The water flies off by centrifugal force, and is collected in and discharged from a second enclosing cylinder. "Separated" milk is obtained by a similar process. The pure milk is placed in a rotating cylinder, and as the cream is lighter than the rest of the liquid, the particles of cream mass themselves in the centre of the cylinder, and the "skim" milk moves towards the sides. *See also* **Centrifugal Casting.**

Centrifugal Pump. — The centrifugal pump, as its name implies, acts by giving to a stream of water such a rapid whirling movement in a circular vessel that the water acquires a tendency to escape radially in accordance with the law which is expressed briefly in the formula:—

$$C = 0{\cdot}00034\ WRN^2,$$

where C is the centrifugal force, W = unit mass, R = radius of revolution in feet, and N = number of revolutions per minute.

The whirling movement is impressed on the water by causing it to enter at the centre of the circular casing in which revolves a fan wheel,

Figs. 151, 152. The water as it travels between the arms or blades of the fan acquires the angular velocity of the fan, and escapes with a tangential velocity equal to that of the tip of the fan

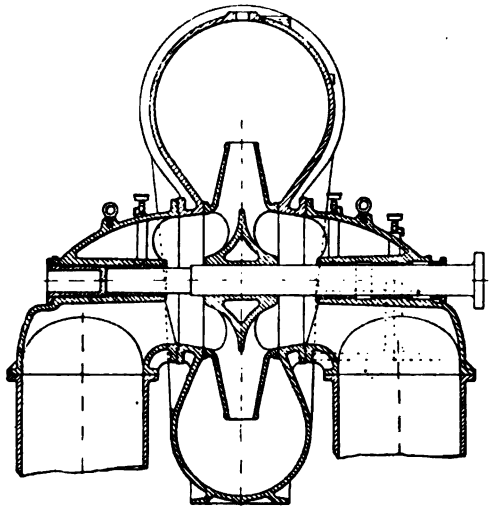


Fig. 151.—Vertical Section.

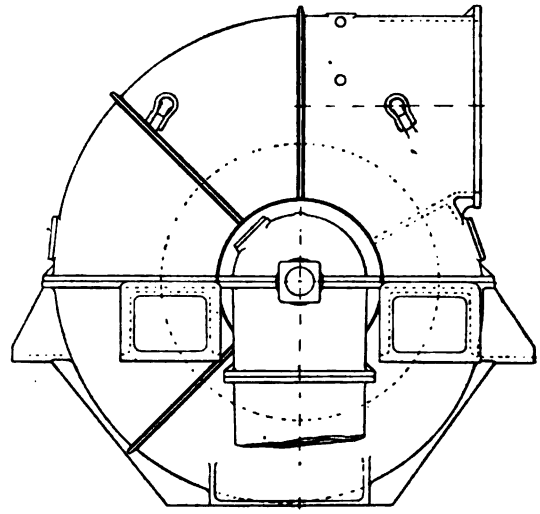


Fig. 152.—Elevation.

52-inch Double Suction Centrifugal Pump. (Tangyes, Ltd.)

blades, and a radial velocity which, if the escape were free, would produce a flow direction compounded of the two motions and a pressure in accordance with the formula just now given.

In the best fans that part of the chamber into which the fan delivers is tapered outwardly so as to produce gradual deceleration of the stream, which then escapes into a spiral snail chamber, of gradually increasing section to the pump outlet fan. Upon the pressure set up by the centrifugal effect depends the height to which the water will rise, and it is found that centrifugal pumps are most efficient at moderate lifts, but that they may be used for high lifts when placed in series, the first pump delivering to the inlet of the second, whereby the pressure produced is cumulative. The small space occupied, the facility of driving direct by electric motor, and the large capacity of centrifugal pumps render them excellent pumps for sewage work, for irrigation, for drainage, and for circulating water through surface condensers.

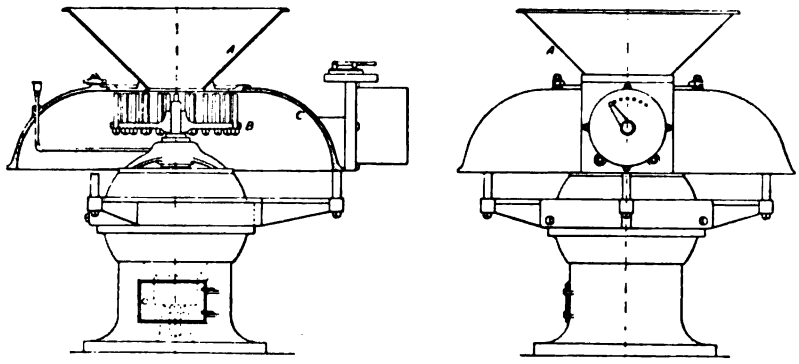


Fig. 154.—Centrifugal Sand Mixer. (Wm. Sellers & Co., Inc.)

When electrically driven, the efficiency of a centrifugal pump and its motor may be assumed as 40 to 50 per cent. of the electrical energy converted into foot pounds of actual lifted water.

Efficiency is much reduced when the endeavour is made to regulate the discharge by choking the supply to the pump. With an air-tight suction pipe and a good retaining valve, and proper means of charging the pump, a centrifugal should raise water from a depth as great as any bucket pump. The writer has

drawn water of 52° temperature from a depth not less than 31 feet below the pump.

V, being the velocity of the fan tip in feet per second, must be 8·8 $\sqrt{H}$ for small fans where H = height of total lift in feet, or 10·5 $\sqrt{H}$ for large pumps.

sion ratio, and such a pump will throw 20,000 to 24,000 gallons per hour to a height of 30 to 24 feet. Fig. 153, Plate XIII., illustrates a Centrifugal Pump.

Centrifugal Sand-Mixer.—This form of mixer, Fig. 154, depends on centrifugal force

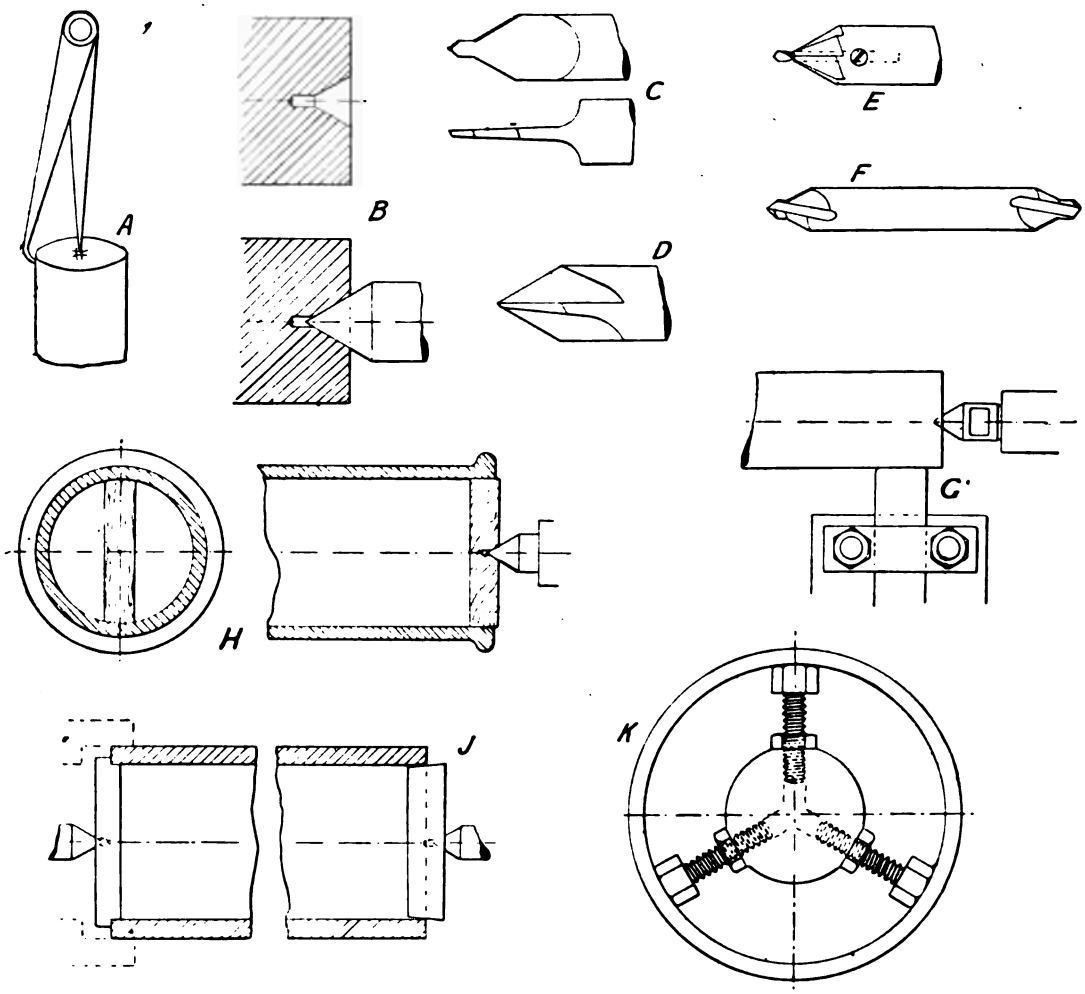


Fig. 155.—Examples of Centring.

G = gallons per minute, d = diameter of discharge pipe in inches, then $d = \frac{\sqrt{G}}{4}$.

D = diameter of fan or runner in inches, then D = 1·5d to 5d.

About 8 feet per second velocity of water in discharge and inlet pipes is usual. A 5-inch outlet with a 15-inch runner is a usual dimen-

for its action; the lumpy sand is fed into the hopper mouth A, and falling upon the vertical prongs on the plate B, is thrown from one to the other rapidly, and finally against the cover C, whence the fine sand falls to the ground. The hopper A is hinged, and secured with buttons, so that it may be turned upwards, exposing the prongs, for their cleaning, or removal of nails,

&c., entangled amongst them. The example illustrated is driven by a motor, with its shaft vertical; other types are constructed to drive by belt. The motor drive has the advantage that the machine can be shifted about the foundry to any convenient locations as required. The shaft makes about 1,200 revs. per minute.

Centring.—The operation of putting the holes in work for support on centres is effected

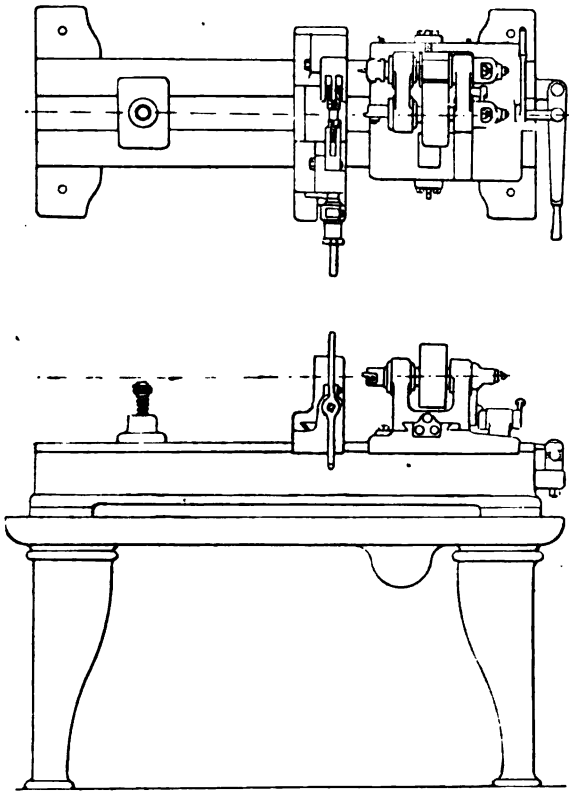


Fig. 156.—Centring Lathe.

either by hand methods, or by the **Centring Machine**. In the first-named mode, the centre of the bar is found, various ways being applicable. In a small diameter it can be judged by the eye; the compass caliper may be used, Fig. 155, A, or the **Centre Square**, or the **Bell Centre-Punch** (Vol. II., p. 125). Centre-punching alone is not a good method for running on the lathe centre, and is unsatisfactory except for the smallest rods. The practice therefore is to countersink truly and then put a small hole at the bottom, B, so that the tip of the centre does not touch the metal. This results in nice running, and the countersink wears evenly, so that the work does not become untrue if in hand for a considerable while. The countersinking is done with ordinary tools, D, and drilled afterwards, or more expeditiously by using a combined drill and countersink, three forms of which are seen at C, E, and F. Perhaps the best and most efficient is F; C is rather weak, and E liable to clog. Its drill is adjustable for length as it wears away. A practice with some turners is to use a square centre, G, the work being centre-popped, and then revolved between centres, the square one in the poppet. This is fed up, and cuts a countersink in the end. The bar held in the slide rest is pressed against the work, to correct any tendency to eccentric running. This method is perhaps of more value in truing centres with diameters, in old work, when it requires re-turning, than for originating new holes, which are more rapidly done by the previous methods illustrated.

Another aspect of centring is that of holding hollow work, as pipe ends, castings, &c., too large to receive any class of solid centre. In this case bridging is resorted to, a bar of wood, H, or of metal, J, being driven into the bore to receive the centre. Sometimes a bolt is inserted on either side of the strip to steady it. Triangular or spider centres are also used, which are automatically self-centring. A very handy type employing screws for adjustment to different diameters is seen at K.

Centring (or Centering) Lathe, or Machine.—The subdivision of tasks in the machine shop has resulted in taking the operation of centring bars for the lathe from the turner, in cases where a sufficient volume of work is handled, and transferring it to a special lathe, which drills the centre holes in the bar ends, and faces the latter neatly. Fig. 156 gives elevation and plan of a type by John Lang & Sons, having a double head for centring, and then facing. The bed carries a head with the spindles; a vice having vee jaws, opened and closed on the work by a right and left hand screw, and a steadying jack holding the bar up. Details of the head are given in Fig. 157.

The base piece A slides on the bed, and is fed up and withdrawn by the pivoted lever B. An upper slide C, holding the spindles, can also be moved crosswise by the handle D, working the lever E which has a pin and roller engaging in the rear. The centre-drill H (which countersinks also) is gripped in a split cone, held on F by a large nut. The facing tool J is a bit of steel clamped down against a shoulder on the end of G. The transverse movement of the

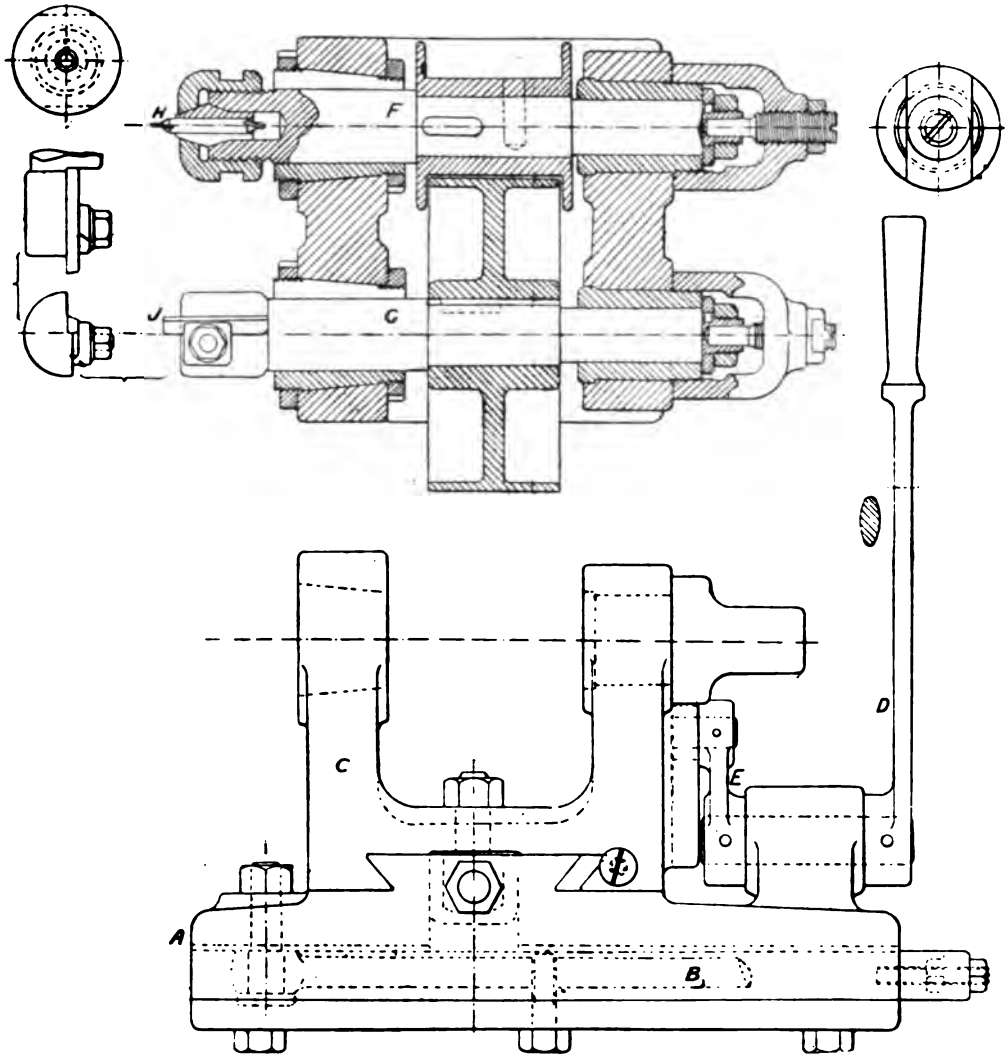


Fig. 157.—Details of Centring Lathe.

a slot in C. This motion serves to bring either the centring spindle F, or the facing spindle G into line with the bar. Both of these run in adjustable split cone bearings. Driving is done by two pulleys, the same belt passing around both, so that suitable relative speeds are obtained. End-thrust is taken by hardened steel pins at slide C enables J to be moved across the end of work of various diameters.

Double-ended machines are also constructed to treat both ends of a bar simultaneously, one head being adjustable for length. Small portable tools carried to the work are also made, being rather more convenient in certain

cases than having to take the bar to a fixed machine.

An example of a portable centring machine is given in Fig. 158, Plate XIII.

Centripetal Force.—*See* **Centrifugal Force.**

Chain Pulleys, or **Chain Wheels.**—These are either smooth or recessed, the first named being deficient in non-slip, the second being capable of giving or receiving a positive pull. These differ from **Rope Pulleys** in the sectional forms of the grooves.

Plain pulleys have two principal shapes of groove, the semicircular and the approximate chain link section. The objection to the first is that the chain is strained by having to lie diagonally in its groove. It is also very liable to take on a twist in its length. In the other section the links lie flat and vertically, the risk of twisting is lessened, but the links that lie flatwise are strained in passing round pulleys of small diameter. Such pulleys are generally cast with a side flange to prevent the chance of the chain surging out of its groove. In a steadily running chain the flanges are often omitted. In either form sufficient side clearance must be allowed between the chain links and the grooves.

In a slightly advanced form used for the small chains employed for hand travellers, ribs are cast on the inner faces of veed sheaves to bite the chain. These are not entirely non-slipping, but they are serviceable for the purpose for which they are used.

Cupped Pulleys.—In these the position of each successive link is absolutely determined by recesses cast in the pulley rim. Such wheels are therefore used for the transmission of power in a precise and positive way. They are not employed for jib head pulleys where there is sufficient tension to prevent slip. But they are used in pulley blocks, in capstans, and for derricking jibs, and similar cases where slip would be inconvenient or disastrous. A very great advantage also is that small cupped pulleys can be used where plain ones could not be, due to the straining of the chain links round the small radii. In the cupped pulley, however small, each link has a flat bedding.

The difficulties due to the use of cupped drums are those resulting from the stretch of the chain. The pattern must be made in the first place to its chain by direct measurement and fitting, but unless all the stretch has been taken out of the chain first, it will not fit after a few weeks or months of service. Obviously the shorter the link the more favourable are the conditions for service.

The Pattern Work, and Moulding of Chain Wheels.—This is rather a large subject, of which the following is a summary only. From this point of view sheave wheels may be classed as those which deliver from a pattern wholly, and those in which cores are used in part or entirely. When wheels deliver they are built up in segments, the smallest alone excepted, in a similar manner to gear wheels. *See* **Segmental Work.** Similarly too the centres may be solid plated, or have arms let in to the rim. And the arms may be jointed along their central plane if of reasonable thickness, or be in one thickness if thin, and one-half the rim will then be fitted as a loose ring without being attached to any portion of the arms, as is frequently done with the patterns of worm wheels. These remarks are applicable to pulleys in general, irrespective of the sectional shapes of their rims.

The rims of plain pattern sheaves offer no difficulties; each half is turned by templet made from the full size drawing. But cupped sheaves have to be marked out very carefully, since if there is the slightest difference between the recesses and the pitch of the chain links, this error becomes cumulative with each successive link. The only safe course therefore is to take a definite length of chain, comprising say from half a dozen to a dozen links, measure that, and divide it by the number of links to obtain the pitch of each link, so averaging inaccuracies. The pitch then is laid out as chord pitch, not as arc pitch, used in the case of gear wheels. Even then it is very desirable to try the chain in the pattern (shrinkage on the length of individual links may be neglected), cutting the recesses full to their lines, say $\frac{1}{32}$ outside of them first, and then reducing until the chain beds properly. There must be no projecting angles at the bridges of metal that intervene, but the chain links must fall into their successive places without hitch. A good deal of rounding of edges is therefore essential.

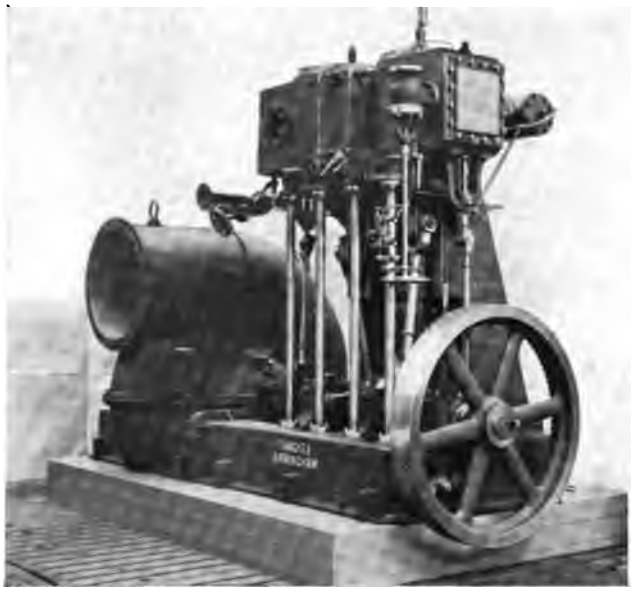


Fig. 153.—Centrifugal Pump.
(Tangyes, Ltd.)



Fig. 159.—Chain Pump.
(Hayward-Tyler, & Co., Ltd.)



Fig. 158.—Portable Hand Centring Machine to attach to Shafts. (E. G. Herbert, Ltd.)

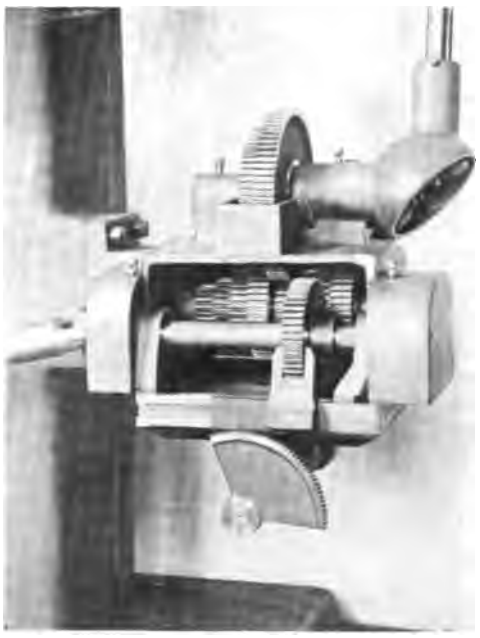


Fig. 170.—Change Speed Gears for Feeds of Cincinnati Milling Machine.

To face page 198.

Core boxes are used when wheels are of large diameter, and especially for jobbing work. The cores are set by a ring print impression swept up, or sometimes built on a pattern. The core boxes must be divided into some aliquot portion of the circle, so as to make joint with the centre of a link space, or a link partition. The cross-section of the space must be exactly that of the rim plus the print section.

The moulding of sheave pulley patterns is done by turning over, and it usually involves a middle box part to take out the rim as a ring of sand. That is the common method adopted in the larger pulleys. But in the smallest pulleys this middle box is frequently dispensed with, and almost always so when the work is standard and done in large quantities. A loose ring of sand is still necessary, but it is made by a down jointing of the sand instead of using a separate middle. It is carried on an iron ring and fitted with a sloping outside joint to the sand in the bottom box. No middle box is necessary when cores are used, since the top faces of the cores coincide with the joint of top and bottom boxes.

Chain Pump.—A pump in which a number of buckets or troughs are carried round two drums, one above, one below in the liquid. They are connected to chains which are driven by the rotation of the upper drum.

The ascending portion of the chain with its buckets is enclosed in a casing of cast iron, with a very slight clearance, so that little of the liquid is wasted. In large pumps this casing is of rectangular cross-section, but in smaller ones, like those illustrated by the photo, Fig. 159, in Plate XIII., the chain comes up through a cylindrical barrel, and the bottom drum is omitted. The value of these pumps lies in their extreme simplicity, and in their ability to lift any kind of liquid or sludge, as manure, tar, sewage, sludge, &c. A man or a boy can operate the smaller sizes, and at sixty revolutions of the handle per minute, from 1,000 to 5,000 gallons of liquid can be raised per hour, according to the bore of the pump.

Chains.—Chains are of three classes, omitting **Pitch Chain**, to be noticed under that head; they are short-link crane chain, short-link chains, and chain cables, the latter comprising short link, and stud link. Each is made in widely different qualities, with corresponding differences in prices, and sizes vary somewhat in the different kinds of chain. The following is a summary of the leading kinds.

Short-Link Crane Chain.—This is made in sizes from $\frac{3}{16}$-in. iron to 2-in. iron; *see* table. It is made of A1 special best best iron. Prices are high, ranging from 94s. per cwt. for $\frac{3}{16}$-in. chain to 26s. 6d. for 2-in. chain.

SHORT-LINK CRANE CHAIN, A1 SPECIAL BEST BEST (JOSEPH WRIGHT & CO., TIPTON).

Size of Chain.	Dimensions over all (Approx.).		Weight per yard (Approx.).	Test Load.		Working Load.	
	Length.	Width.	Lb.	Tons.	Cwt.	Tons.	Cwt.
$\frac{3}{16}$	$1\frac{1}{8}$	$\frac{3}{4}$	1.68	...	$8\frac{1}{2}$	...	5
$\frac{1}{4}$	$1\frac{1}{4}$	$\frac{7}{8}$	2·5	...	15	...	9
$\frac{5}{16}$	$1\frac{3}{8}$	$1\frac{1}{8}$	4	1	$2\frac{1}{2}$	...	$13\frac{1}{2}$
$\frac{3}{8}$	$1\frac{13}{16}$	$1\frac{5}{16}$	5·75	1	$12\frac{1}{2}$	...	$19\frac{1}{2}$
$\frac{7}{16}$	$2\frac{1}{8}$	$1\frac{9}{16}$	7·5	2	5	1	7
$\frac{1}{2}$	$2\frac{3}{8}$	$1\frac{13}{16}$	9·4	3	0	1	16
$\frac{9}{16}$	$2\frac{3}{4}$	$1\frac{15}{16}$	11·5	3	15	2	5
$\frac{5}{8}$	$2\frac{7}{8}$	$2\frac{3}{16}$	14·5	4	$12\frac{1}{2}$	2	$15\frac{1}{2}$
$\frac{11}{16}$	$3\frac{1}{4}$	$2\frac{7}{16}$	16·5	5	$12\frac{1}{2}$	3	$7\frac{1}{2}$
$\frac{3}{4}$	$3\frac{9}{16}$	$2\frac{9}{16}$	19·5	6	15	4	1
$\frac{13}{16}$	$3\frac{3}{4}$	$2\frac{13}{16}$	22·5	7	18	4	15
$\frac{7}{8}$	$4\frac{1}{8}$	$2\frac{15}{16}$	25·5	9	$2\frac{1}{2}$	5	$9\frac{1}{2}$
$\frac{15}{16}$	$4\frac{7}{16}$	$3\frac{1}{8}$	29	10	10	6	6
1	$4\frac{3}{4}$	$3\frac{7}{16}$	33·6	12	0	7	4
$1\frac{1}{16}$	$5\frac{1}{8}$	$3\frac{5}{8}$	38	13	10	8	2
$1\frac{1}{8}$	$5\frac{3}{8}$	$3\frac{7}{8}$	42	15	$2\frac{1}{2}$	9	$1\frac{1}{2}$
$1\frac{3}{16}$	$5\frac{5}{8}$	4	45·5	16	18	10	3
$1\frac{1}{4}$	$5\frac{7}{8}$	$4\frac{3}{16}$	50	18	15	11	5
$1\frac{5}{16}$	$6\frac{1}{8}$	$4\frac{7}{16}$	54	20	$12\frac{1}{2}$	12	5
$1\frac{3}{8}$	$6\frac{1}{2}$	$4\frac{3}{4}$	60	22	$12\frac{1}{2}$	13	10
$1\frac{1}{2}$	$7\frac{1}{8}$	$5\frac{1}{4}$	72	27	0	15	0
$1\frac{5}{8}$	$7\frac{11}{16}$	$5\frac{5}{8}$	84	31	$12\frac{1}{2}$	17	5
$1\frac{3}{4}$	$8\frac{5}{16}$	6	99	36	15	20	0
$1\frac{7}{8}$	$8\frac{7}{8}$	$6\frac{1}{2}$	114	42	$3\frac{1}{2}$	23	0
2	$9\frac{1}{2}$	7	129	48	0	26	0

Short-Link Chain.—This is made in the same dimensions as the preceding, but in four different brands. The cheapest is *rigging chain*, not tested, ranging from 34s. 3d. to 13s. 9d. in $\frac{3}{16}$ in. to 2 in. respectively. The next is *best chain*, tested and examined, at from 45s. 6d. to 15s. The third is *B*, *B crane chain*, tested and

examined, at from 55s. to 17s. 3d. The working loads are less than the special best first mentioned, being 3½ cwt. against 5 cwt. in the $\frac{3}{16}$-in. chain, and 384 cwt. against 520 cwt. in the 2-in. The fourth is the *best best crane chain*, tested and examined, at from 73s. 6d. to 19s. respectively, and working load of 4¼ cwt., and 480 cwt., or nearly as good as the special best.

Chain Cables. — Short link is made from $\frac{3}{8}$ in. to $1\frac{5}{8}$ in. in four grades. *Stud link* also in four grades, from $\frac{3}{8}$ in. to 3 in. Only the previous kinds are employed for general engineering purposes, the cables being chiefly used for moorings.

The short-link, or close-link, chain is made to certain proportions given in the table adjacent, being the shortest lengths that can be conveniently welded up, having to be done link by link by hand, or by the aid of dollies (dolly welding). The shortness of the links is an advantage, because they do not stretch so much under test, and in use, as longer links, and they do not require studs; neither, being more flexible, do they suffer so much through being strained by bending round pulleys of small diameter as those of greater length do.

The amount of stretch under stress of the common or long-link chains is an element of weakness. But for the studs, the links would break at a stress considerably below the proper breaking stress. The studs prevent this by keeping the sides from collapsing. They do not add to the strength directly, but indirectly by reinforcement, so that chains can withstand heavier loads than open link ones of the same size.

The common chain has the advantage of lightness over the close-link, but this does not count when hauling and lifting are in question against the superior strength and reliability of the last named.

A close-link chain requires a longer link, a *shutting link* made, when a piece has to be attached, such as a swivel or another length of chain. The shutting link is made of iron $\frac{1}{8}$ inch larger than that of the chain, because the chain has been stretched by its testing, and the new link has not. Also it is made longer, by the amount of diameter of the iron, or more, because there are portions of two links in it instead of one only, as when a new chain is being made.

Chains develop a twist in manufacture, which is apparent in long lengths, often amounting to a complete twist in a length of 20 feet. This must be taken out before pulling the chain over its pulleys, and it is done by laying it along on the ground, and twisting it in the opposite direction.

The absolute strength of chain links is not equal to that of the iron from which they are made, but is from 25 to 30 per cent. less. The tensile strength of BB chain iron is about 26 tons per square inch, with an elongation of 15 per cent., and a contraction of area of 20 per cent.

The Care of Chains.—Chains are subject to rapid deterioration under some conditions of working. They suffer much in foundries where air is charged with sulphur; in gas works, and on coal sidings where dust is plentiful. Even under the most favourable conditions, in a clean atmosphere, and under easy duty, a chain should not be worked for more than a twelvemonth without being annealed, and examined; when under severe duty, and in a bad atmosphere, examination should be made after every few weeks. Annealing is performed either by putting the chain into a reverberatory furnace, or into a core stove for a night, the temperature not exceeding a red heat, which is then allowed to cool down, or it is put into a wood fire for several hours. Chains may be allowed to cool down in the furnace, or be taken out and covered with sand or ashes. To anneal chains with wood they can be laid on a grating of loose iron bars supported on bricks, and the fire built underneath.

Passing a chain through a fire or a stove restores the metal to its normal condition, and it also burns off all grease, and enables any imperfect cracks to be seen. These have to be sought for link by link. The chain is suspended over a pulley and is drawn over slowly, the links being struck one by one with a hammer, and examined carefully. Cracks are thus detected, and any faulty links are cut out and removed, and the sound portions welded up into a fresh length of chain. Before a chain is put

into service again it is given a coat of boiled linseed oil, or of tar, while hot.

Another test is that for reduced dimensions. Chains wear down on their sides by contact with their pulleys, and this is rapidly accelerated by the presence of grit. So that even though they retain their soundness, their strength is reduced in proportion to their diminution in section. These therefore must be removed to lighter service, or when practicable their loads must be reduced where they are working. This rapid wear may generally be prevented by abundant lubrication, but oiling is not done on sling chains, though in most hoisting machinery it may be.

Deterioration of chains due to internal changes, termed crystallisation, is readily removed by annealing; but defects in welding, and wear and tear due to the movements and stresses producing friction and strain are not so readily guarded against. Welds are sometimes of a surface character, the edges being united, but enclosing scale. The result is that a chain may pass its proof load, and be used until friction has removed the outer sound welding, and then snap when the region of scale is exposed. The high factor of safety will permit of such an event happening.

Chains are badly served and strained when they run over pulleys having narrow rather than flattish grooves, the result being a rolling movement, which favours a development of twist. A twisted chain wears faster than one which lies straight. Narrow grooves also wear the sides of the links. Small pulleys strain chains by bending or knuckling them, or by wearing the ends, or "socketing." The crushing action is most severe here in the hollow. Lubrication is a great agent in the lessening of this form of wear.

A most severe kind of stress on a chain is that of sudden shocks, due to slip of a crane load, or sudden arrest of its motion as in heavy braking. It may be so severe as to strain the chain beyond its elastic limit, with permanent deformation, and some drawing in of the links, and it accelerates the wear in the ends (socketing). Severe cold tries a chain much as it does cast iron, rendering it more brittle.

Chain or Chain-Saw Mortising Machine.—This is a machine which carries an endless steel chain having teeth formed upon the links, constituting what amounts to a band-saw of extra width. The chain is driven by a sprocket at one end, and runs on a ball-bearing disc at the other, the back of the teeth being supported by a flat bar. A high speed is given, about 1,500 ft. per minute, and the chain is sunk into the wood as it cuts. The action is very rapid, owing to the number of teeth at work, and the chips are carried upwards by the rising side of the chain. Slots and mortises are produced with much greater expedition than the chisel method, and blank-ended slots are as easy to make as thoroughfare ones. Fig. 160 gives views of the links of two chains, from which the tooth shapes can be noted. The one

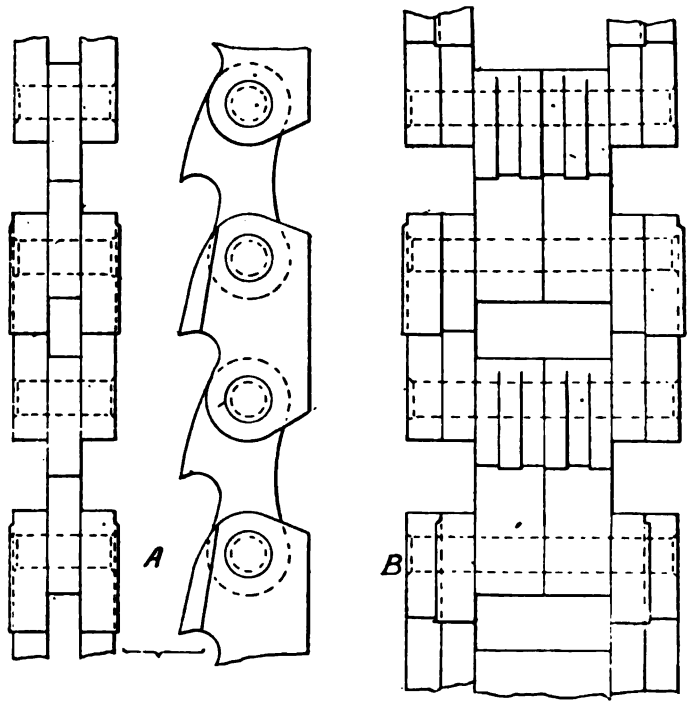


Fig. 160.—Links of Chain Mortiser.

A has thirty-four links, and cuts ¼ in. wide; B cuts to 1 in. It will be seen that B has extra teeth, both on the outside and on the central links, these being staggered or alternated in successive links to ensure good working. The smallest chains sometimes have curved backs, to run on a bar of small radius, when cutting narrow slots. Fig. 161 shows a side elevation of the New Britain machine (J. B. Stone & Co.). The driving of the chain is effected through the fast and loose pulleys A, to pulley B, thence to

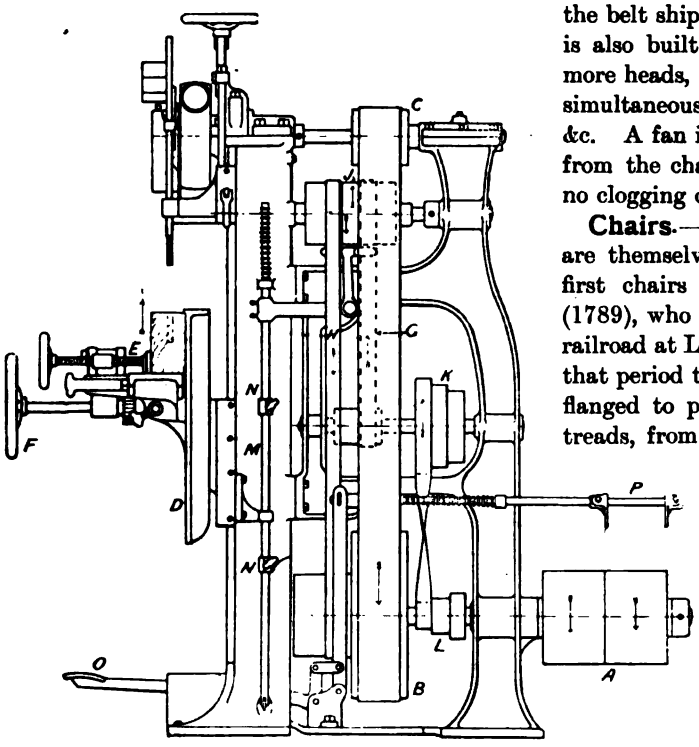


Fig. 161.—Chain Mortiser.

C, which rotates the chain sprocket, the top portions being protected by guards. The table or knee D is provided with a vice E, closed upon the work by handwheel and screw, and another wheel F gives the longitudinal feed by rack to the sliding table carrying the work past under the chain. The vertical feeding is effected by power, as well as the quick return. A vertical screw within the frame at the front works in a nut on the knee D, and thus moves the latter up or down, according to whether a belt G, or another H is thrown from loose pulleys on to a fast pulley J, connected by bevel gear to the vertical screw. G is driven through three-stepped K from a cone L, thus giving varying rates of feed to the work, as desired. Belt H runs at a constant speed for rapid return. Control of these belts is by the rod M, moving the belt forks beneath J. The reversal is automatically obtained for repetition work by the adjustable dogs N, N, struck by the projecting arm of D, so throwing M up or down. The whole machine is stopped by foot lever O moving the belt shipper P. A similar style of machine is also built in "gang" form, having two or more heads, so that several mortises can be cut simultaneously, for such work as doors, panels, &c. A fan is employed to suck away the chips from the chains in all these machines, so that no clogging or inconvenience is caused.

Chairs.—The supports of railway rails which are themselves attached to the sleepers. The first chairs were devised by Mr W. Jessop (1789), who adopted them when constructing a railroad at Loughborough in Leicestershire. At that period the tram lines were made with rails flanged to prevent the wheels, which had flat treads, from running off. Mr Jessop was the first to reverse the design by making the rails with flat tops, and flanging the wheels. The rails—fish-bellied—were of cast iron according to the practice of the period, and the lugs by which they were pinned or bolted to the sleepers gave trouble by fracturing. Mr Clement Stretton says that "this led to a great and important improvement. The base was removed from the rail itself and cast as a separate 'chair' or 'pedestal,' the rails were fastened by pins passing through holes in the upright sides of the chairs, and corresponding holes in the ends of the rails."

It would be interesting to trace the chair through its various forms on different lines, and in different countries, but that cannot be done here. We must simply note the two or three leading forms in use in Britain.

Flat-bottomed rails do not of necessity require chairs, though they have sometimes been

adopted. Such rails, in which bridge rails are included, can be spiked down to longitudinal sleepers readily, and to cross sleepers also. But the double-headed rail must have chairs, not only to support it, but to distribute the weight over an area much larger than that afforded by the base of the rail. Hence we have the first conditions; an ample area of base, and ample security afforded to the otherwise unstable rail in the lateral direction. This task of securing is not so simple a problem as it appears on first thoughts, and there are many differences in design.

One side of the rail is driven hard by the wedge against one side of the recess in the chair, Fig. 162 (1), *a*, to maintain the gauge correctly. It varies, being inner or outer on different lines. The bottom of the rail must bed firmly on the bottom *b* of the recess, and so the driving of the wedge is made to effect this by virtue of the upward curved shape of the portion of the recess *c*, against which the wedge takes its bearing. Unless the rail is thus pressed down firmly, the hammer blows of the traffic will produce indentations on the underside of the rail. Also the height of the chair must be kept down sufficiently to prevent contact between it and the flanges of the wheels as the rails wear down. The chair must be strong enough to withstand the wedging and the hammering of the traffic without being heavier than necessity demands. It is therefore generally a ribbed casting, spreading out very much at the base, and often hollowed underneath.

Pattern Work and Moulding.—Chairs are made in such quantities that a special department of the railway foundry is set apart for their moulding and casting, and a special cupola retained for the metal. Generally it takes two or three men to mould a chair, one doing the top, the other the bottom, while a third may close the moulds. They are done by plate moulding, and machines may or may not be employed.

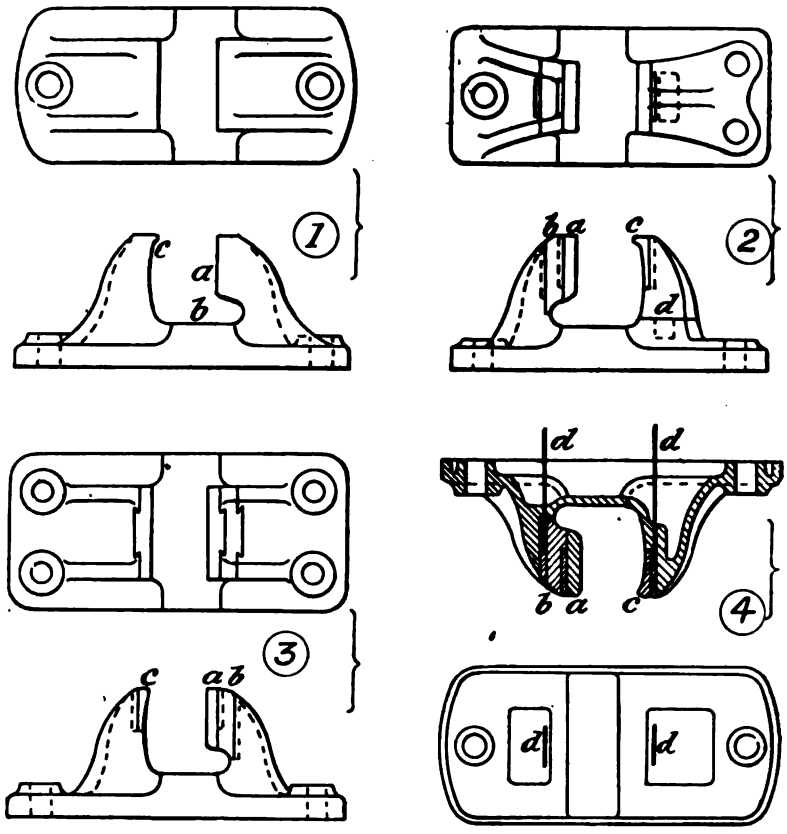


Fig. 162.—Chairs and Chair Patterns.

The patterns, Fig. 162 (2-4), are made in cast iron, tooled and polished all over, and beeswaxed, or blackleaded. They are lightened, to lessen the weight of lift, and nothing is cored, but the pattern is like its casting save for the leaving certain pieces loose. These comprise the portions overhanging the rail space which are fitted in different fashions, but in whatever way fitted nothing is left for the

moulder to adjust. The loose pieces fit precisely without any trouble with skewers. Dovetailing is the principal device, the loose parts being fitted with sliding dovetails to the horns of which they form a portion. On the side where the overhanging is greatest, two loose thicknesses are necessary, Fig. 162 (2, 3), *a*, *b*. Sometimes the hinder pieces, Fig. 162 (4), *b*, *c* are carried by strips of metal *d*, *d* soldered to them, and coming up through holes in the body of the pattern. When patterns are moulded by hand on plates without the aid of a machine, the lessening of their weight is of importance. They are therefore lightened out at the back, Fig. 162 (4). The object of tapering the sides

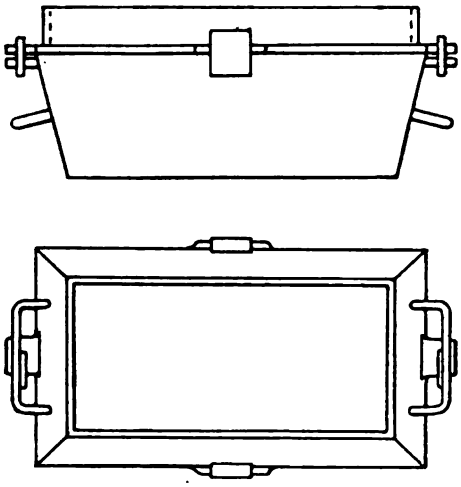


Fig. 163.—Moulding Box for Chairs. Elevation and Inverted Plan.

of the bottom moulding-box part, Fig. 163, is to lessen the amount of sand and ramming required. This apparently trivial detail is an element in economy when chairs are being moulded all the year round.

Chalk is a very pure form of limestone containing about 98 per cent. of carbonate of lime, $CaCO_3$. The remaining percentage of impurities consists of silica, alumina, and magnesia. The wolds of Yorkshire and Lincolnshire, the white cliffs of the south coast (Albion = Lat. *albus*, white), the Chiltern Hills, and the North and South Downs are composed of chalk. Heated in the lime kiln it becomes quicklime, CaO.

$$CaCO_3 = CaO + CO_2.$$

Used with clays, chalk forms various cements, the chief among them being Portland cement. When ground and washed to separate impurities present, chalk becomes "whiting." Its whiteness and friability render it invaluable to the teacher, and it is also because of these two properties that the engineer uses chalk—for whitening the surfaces and edges of timber and metals to show clearly scribed lines and centres, in all kinds of marking out done in pattern shop, boiler shop, and machine and fitting departments.

Chalk Line.—A length of fine cord or twine usually kept wound on a reel or in a case, and coated with chalk. It is used by carpenters, pattern-makers, and boiler-makers for marking long straight lines between two given points on the surface of material, or drawing boards. In carpentry it is chiefly employed for marking sawing lines lengthwise on planks. It is used by holding it at each end, tightly stretched along the surface where the line is wanted, and then forcibly raising the middle part a few inches and allowing it to spring back again. This transfers a rough but straight line of chalk to the surface. The alternatives to the use of a chalk line are a long straight-edge to rule the line by, or a base line or edge from which it can be gauged or measured.

Chambered Core.—A core which is enlarged or bellied at its central portions. Its utility is two-fold. It diminishes the length for boring in a deep hole, and it prevents or lessens risk of the drawing or fracturing of a big boss.

Chamfer.—A bevelled edge.

Change Gears or **Change Wheels.**—There are few elements of mechanism which are of greater value than the gears by which variable rates of traverse are imparted to screw-cutting tools in the lathe. There is much similarity between change and feed gears; in fact the same set is often used in some lathes for both classes of work. But it will be better to separate the description of feed gears from the others, because of the differences usually made in the methods of operating them.

Keeping therefore strictly to the change gears for screw cutting, there are two types, the

ordinary, or separate wheel kind, which is the older, and most common, and the nest, or group type, of comparatively recent origin, and used to a much less extent than the other. The germ of the last named appears to have been in a patent by Edward Bancroft and William Sellers, No. 10,491, 7th February 1854. But the origin of the first goes back beyond the middle of the seventeenth century. Holtzapffel figures a lathe from a French work by Thiout, 1741, in which change wheels are shown, and which, though crude in the extreme, embodies a simple train. The fact that it was used for cutting threads upon the fusee barrels of clocks does not affect the principle. The links in the history of change gears do not seem to have been chronicled. Many old lathes long since gone to the scrap heap had the same arrangements as those of the present time, only that they were built in a more skeleton-like fashion than those of the present.

To use a master screw as a guide for cutting another screw of the same pitch would not require any great inventive ability. It is done regularly in the Fox lathe, and in the old traversing mandrel type, but a distinct advance was made when the idea of change wheels was suggested. Cords would not fulfil precise requirements, though a Besson lathe of date 1569 embodied an arrangement of pulleys and cords operating the tool from a master screw, used for cutting threads on fusee barrels. Change gears can be so arranged as to impart equal rates of revolution to the work as to the lead screw, or to accelerate, or retard the rate of revolution. As toothed wheels are used, these furnish by multiplication and division a wide range of ratios, but they do not cover all numbers such as primes, nor all fractions, for many of which special wheels are required. *See* **Screw Cutting**.

At present we are only concerned with the arrangements of trains of wheels by which the work is rotated at variable rates by a screw of unvarying pitch. The ratio between the two rates of movement is also the rates of the wheels, so that it is a matter of simple multiplication and division.

Essentially the change gears comprise a number of toothed wheels, ranging from twenty-two upwards, selection from which is made to vary the relative rates of revolution of the lathe spindle, and the lead screw or master screw. The connection between the lathe mandrel and the end of the lead screw is seldom made directly, but through an intermediate wheel or wheels, the studs or axes of which are carried on the swing plate, or quadrant plate pivoted on the left-hand end of the lead screw. This is a most valuable device, for the fact of the studs being adjustable in their slots in the swing plate, and the whole plate movable around an axis, gives a wide range of adjustments of centres, which could not be obtained if centres were rigidly fixed in the line connecting the centres of the spindle and guide screw. It also allows of the introduction of an idle wheel for changing the direction of rotation, so that both right and left handed threads can be cut with the same set of gears.

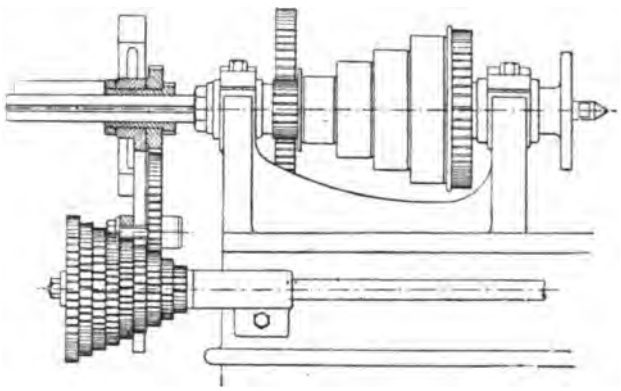


Fig. 164.—Early Form of Nest Gears.

The difference between a simple and a compound train is, that the first comprises two wheels only, the second four, six, eight, or more. It is obviously impossible to connect for high ratios between the two fixed centres of the mandrel and lead screw, for if say a ratio of 25 to 1 were wanted, wheels of say 20 and 500 would be required, which is impracticable. But the ratio can be obtained by other combinations in a compound train.

The mechanical details of these gears involve the swing, or quadrant plate, pivoted on the

... and capable of being ... by two bolts. This move- ... in the plate along which ... slide that carry the inter- ... permits of a large range of ad- ... There are two studs, one short for ... intermediate idle wheels, the other long ... intermediate compounding gears set ... side. It is not usual to change the ... on the lathe spindle if it can possibly be put into operation by a sliding pinion, which is thrown into engagement with either one, so varying the rate of movement of the lead screw. This is a statement of the general design, which is subjected to much detail. As already noted, the idea dates from 1854. Eight or more other patents on the subject appeared between then and 1892, when the Norton patent was taken out, supplemented by another in 1894. The arrangements were varied much in these efforts,

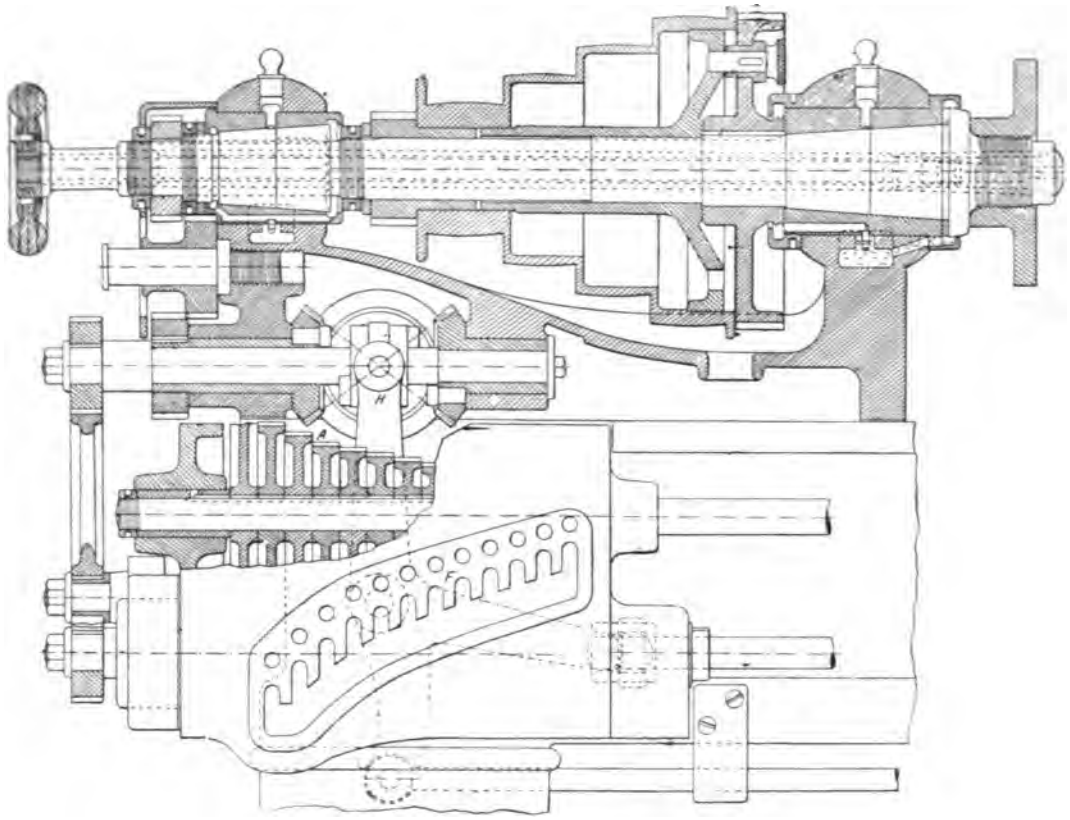


Fig. 165.—Hendey-Norton Change Gears. (Longitudinal Part Section.)

avoided, but that on the lead screw axis is changed as well as the intermediates. The wheels have cut teeth in the best modern practice, and they are of fine pitch, and are retained on their studs with keys. All wheels interchange with each other.

The trouble involved in frequent changing of wheels has led to the design of the nest type of change gears. In this the series of wheels is arranged on a single shaft, and either one is the gears being outside the bed in some, Fig. 164, and unprotected. The Norton design, variously adapted, is used not only in many lathes, but on some other machines. Many patents have followed by other inventors, most of whom embody the cone of gears in the design.

The Hendey Machine Company's head, Figs. 165, 166, comprises the nest of twelve spurs, A, keyed to the end of the lead screw. A shaft B below carries a wheel C, engaging with another D.

The latter is held in a rocking frame, so that it may be thrown into mesh with any one of the twelve spur gears, by moving the handle E up into the slots on the plate F (seen in the front view), and locking by means of the spring catch G slipping into the holes above the slots. The rotation of wheel C is given by a large spur meshing with a small one on the shaft B, the large wheel being driven from the gears at the tail end of the headstock. A set of reversing bevel gears at H provide for right and left hand cutting. This reversal is effected by the rod, seen below the lead screw end, actuating the lever seen dotted in the front view. The feeding may be automatically thrown out at any predetermined position by the smaller rod, seen at the bottom, below the bed, this being struck by a dog in the carriage, so jerking the clutch of H into "no gear." The regular range of ordinary threads obtained – 6 to 20 may be altered by varying the ratios of the gears from the headstock end.

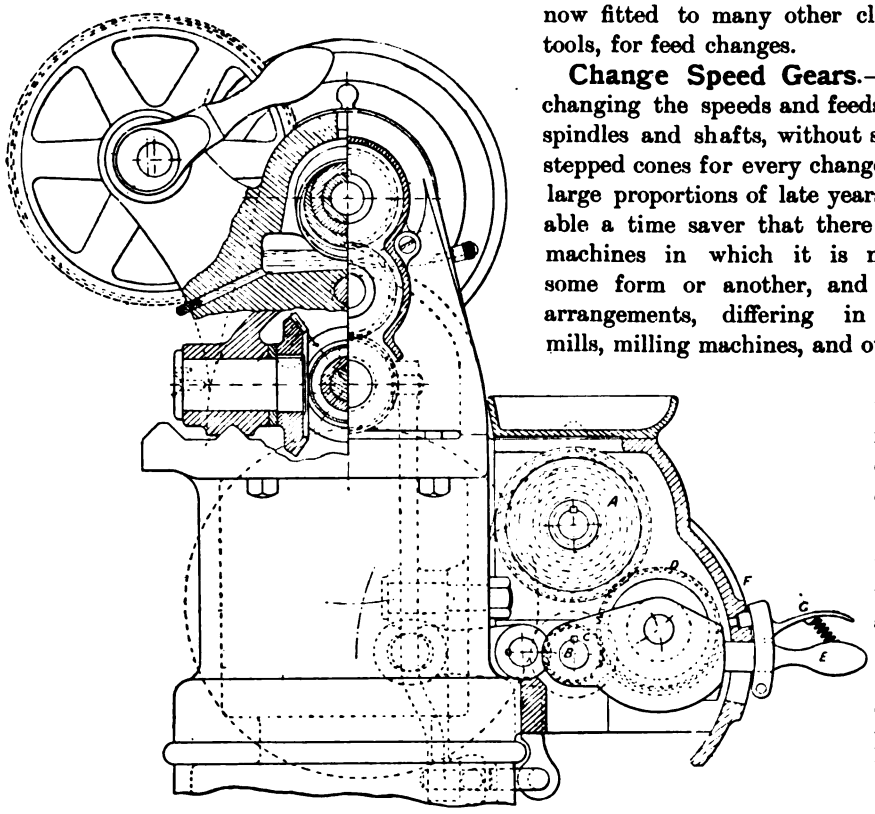


Fig. 166.—Hendey-Norton Change Gears. (End View.)

These gears, originally applied to lathes, are now fitted to many other classes of machine tools, for feed changes.

Change Speed Gears.—The practice of changing the speeds and feeds of machine tool spindles and shafts, without shifting a belt on stepped cones for every change, has grown into large proportions of late years. It is so valuable a time saver that there are few modern machines in which it is not embodied in some form or another, and there are many arrangements, differing in lathes, boring mills, milling machines, and others.

The principal methods, variously modified, may be divided under two classes; those in which gears slide, and those in which a sliding key engages gears which do not slide.

The simplest sliding gears are perhaps those in which three wheels solidly united are slid bodily by a sleeve, Fig. 167, so that each of them may be brought into engagement with its fellow on a shaft lying parallel therewith. Each combination thus gives a different speed from the rest. To ensure each gear mating

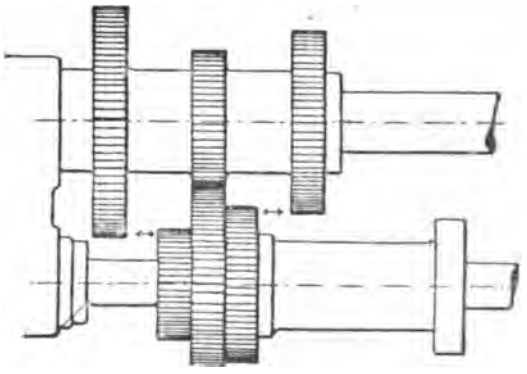


Fig. 167.—Change Speed Gears.

with its fellow, the lever used for throwing it over is locked in a separate pin hole for each wheel. An alternative to this method of direct sliding is to utilise clutches for making and breaking connection.

The objection to sliding gears and clutches is the trouble of making rapid engagement at

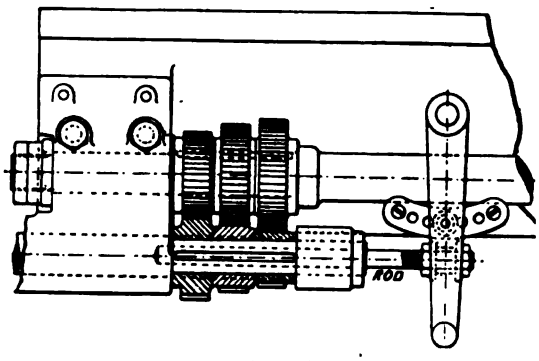


Fig. 168.—Sliding Key Device.

high speeds, without risk of fracture of teeth, with accompanying noise in the heavier gears. The key device, Figs. 168, 169, is therefore rapidly becoming a favourite. In this the gears are always in mesh, but while one set is keyed on its shaft, the other set runs loosely, and is only connected for driving by the insertion of a sliding key in a key groove in the bore. It seems at first sight a rather unsatisfactory mechanism, but as the key is pushed by a strong spring it holds and drives satisfactorily. Advantages of this method of making connection are, that as no endlong movement of the gears

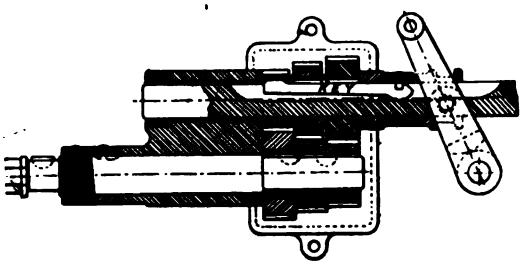


Fig. 169.—Sliding Key Device.

is required, the arrangement is most compact, and a large number of changes can thus be provided for in a nest enclosed in a small box.

Machine tool change speed gears are nearly always of the type in which spur gears can be meshed together in pairs, according to the speed ratio desired by the operator. In some few cases the wheels are always in mesh, and are brought into operation by means of claw clutches. In America, expanding pulleys take the place of change speed gearing to some extent. Generally, however, the employment of "high speed" steel necessitates a more powerful method of driving, so that the constant speed belt in conjunction with a speed gear is the more usual combination.

Fig. 170, Plate XIII., illustrates a change speed set, operated by throwing the wheel seen in the front into engagement with those in the nest.

The necessity for change speed gears has arisen of late years for automobiles having internal combustion engines as prime movers. For machine tools the conditions that have to be fulfilled are much less severe than in automobile work. Machine tools are chiefly in the hands of those who are to a certain extent skilled in the use of such appliances, whereas this is by no means always the case with automobile gearing. In addition to the risk of unskilful handling the gearing is exposed to more shock on motor vehicles, and has to be changed from one speed to another while running. The ideal gear would be that in which it would be possible to work at any speed from zero to the maximum, by infinitesimal degrees.

For automobiles the most generally used speed gear is of the sliding pinion type. In this the driving shaft, driven by the engine through a friction clutch, carries a series of spur pinions arranged to slide on the shaft, which is squared or provided with feather keys to compel the pinions to revolve with it. The pinions correspond in number with the number of speeds required, and they can be brought successively into gear with spur wheels on the driven shaft, whence the power is transmitted by chain, or shaft, to the driving wheels of the vehicle. Though crude and unmechanical, this form of gear survives, many manufacturers having abandoned more scientifically designed gears in its favour on account of its simplicity from the maker's and user's point of view. The chief, and almost only, disadvantage of this type of gear is the battering to which the ends

of the teeth are subjected when coming into mesh. In the hands of a skilful operator this can be minimised to a large extent by only changing from one speed to another when the gear wheels are revolving at, as nearly as possible, the same velocity at their peripheries. Sliding keys, claw clutches, and similar devices have been used in endless variety, the main object being to keep the wheels always in gear; all except those in use at the moment being free to revolve on one, or both, shafts. One design employed wheels always in mesh, those on the driven shaft being normally free to revolve thereon until required. The clutching to the shaft was accomplished by making the shaft hollow with a cam rod within it. This cam rod operated the tail ends of levers, which projected through holes in the hollow shaft, and brought into action pawls engaging with ratchet teeth cut in the driven gear wheels. With the hollow shaft made large enough for the power it had to transmit such a gear gives satisfaction, but in the event of the main clutch being allowed to come into action too suddenly there is a danger of twisting the shaft, especially where this is slotted for the tails of the pawls to pass through.

A form of change speed gear, more in use in America than here, is the Epicyclic. Though more expensive to construct, this type has much to recommend it. It is practically impossible to damage it when changing from one gear to another, and the load is taken up very gradually on each speed. In a few instances the main clutch is dispensed with and the gear alone relied on to take up its work without shock. In general, the epicyclic gear consists of a central driving pinion secured to the first motion shaft. Meshing with this pinion there are usually three or more pinions (planetary gears) free to revolve on their spindles, which latter are supported in a plate free to revolve about the driving shaft as a centre. In addition to meshing with the central pinion the planetary pinions are also in gear with an internally toothed ring, around the outer circumference of which a brake band can be applied at will. When the ring is left free the plate carrying the spindles of the planetary pinions will be stationary, although the driving pinion in the centre is running. The internally toothed ring will, however, be revolving in the opposite direction to the driving pinion, and at a speed in direct proportion to the numbers of the teeth in the driving pinion and ring respectively. On applying a brake to the ring, the plate carrying the planetary pinion spindles will gradually commence to revolve in the same direction as the driving pinion, until the ring is held quite stationary when the plate will be running at its maximum speed. With this form of gear the ratio of speeds between the driving pinion and the plate will always be directly as the number of teeth in the pinion and ring *plus one*. That is to say, if the number of teeth in the pinion and ring are as *one to three*, the speed ratio will be *one to four*. The chain wheel for transmitting the power to the driving wheels of the car is secured to the plate which carries the planetary pinion spindles. Some variation of speed is obtainable by allowing the brake band to slip, more or less, but at the cost of wear on the band and ring, and such a proceeding is only to be recommended in the case of starting from rest, when no main clutch is provided. A reverse drive is obtained with a similar gear, but the internally toothed ring is made the driven member, and the brake band is formed as part of the plate carrying the planetary pinions.

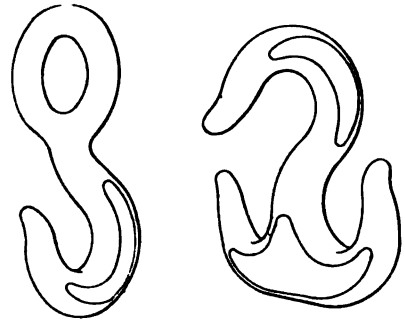


Fig. 171.—Changing Hooks.

Change Wheels.—*See* **Change Gears.**

Changing Hooks.—Fig. 171 illustrates two forms of these, employed for transferring a load from one crane to another adjacent, the chief use being in foundries, where jib cranes take ladles of molten metal from each other. The alternative to their use is to slip the hook

of the receiving crane through the chain sling, hoist up, and so ease off the other hook, until it can be pulled out of the sling.

Channel Rolls.—Fig. 172 shows finishing rolls for channels. The first section seen to the left has already been produced from an ingot in successive passes through cogging, and roughing rolls. Note should be made of the gradual reduction in the angle of slope of the sides, tracing it from left to right. This is done with the object of reducing the labour of rolling, and the tearing action which goes on in perpendicular sides, due to the difference in the speed of travel of those parts of the rolls nearer to and farther from the centre. The square edges only occur in the two finishing passes, by which time the work of reduction has been practically completed. Channels can be rolled of various thicknesses in the web by keeping the rolls apart. But a large increase in thickness would result in fins.

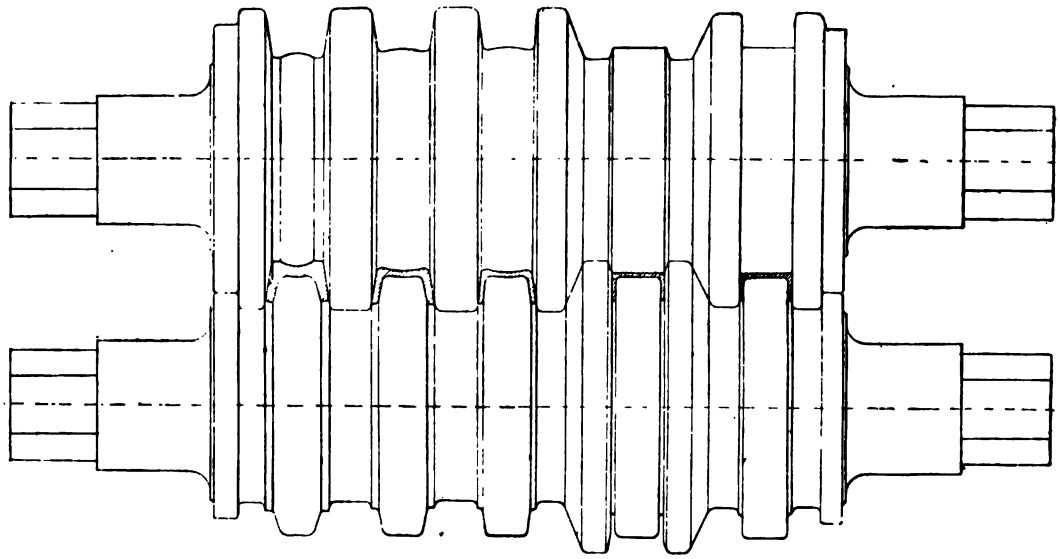


Fig. 172.—Channel Rolls. (Thos. Perry & Son, Ltd.)

Channels.—Rolled sections ⊏ used in constructional work. They are the equivalent of three plates united by right angles. They range through a large number of dimensions, from 1¼ in. wide to 15 in. The term embraces the ordinary channels, the car truck, the special road, and the shipbuilding kinds.

Chaplets, Chaplet Nails, Anchors, Soldiers, Stays, Stops, Studs, are the names of the metallic supports given to cores distinct from print impressions. They are inserted at some considerable distance away from the prints, to prevent dropping of the cores in consequence of their weight, and lifting due to their buoyancy by comparison with metal; or as a substitute for prints where these cannot conveniently be employed. The objection to chaplets is that the metal is liable to become blown in their vicinity, due to the evolution of gas, as from steam generated from moisture, or carbonic acid gas from rust. To prevent this risk, chaplets are tinned, or burnt, or oiled.

The plainest chaplets are the pipe nails, Fig. 173, made, A, in cast, or malleable cast iron, or by riveting a head on a shank, B, C. The concave head, B, is preferable for the support of cylindrical cores when the metal is only of ordinary thickness. These are pushed into the sand, and either take their bearing against the flat bar of the box, K, or against a plate bridged across the edges of vertical bars, or they are driven into a block of wood embedded in the sand (*the chaplet block*), J.

There are many cases where this is impracticable, as where for instance a pointed nail cannot be driven securely, and specially where the cores are very heavy. Then the chaplet is

made like D, E, or F; the first two comprise two plates riveted to a stem, the third is made by casting a solid iron stud. The distance over the faces is equal to the intended thickness of metal. The reason for substituting the solid stud for the two plates and stem of the previous ones is, that these in massive work would become melted before the metal had set sufficiently to prevent risk of the core moving. The solid one does not melt so readily, and so it supports the core until it is carried safely on solidified metal.

In very heavy work reliance is not placed on single studs, but three are riveted together as in G, H. At the other extreme, where the pressure or weight tending to cause the cores to move is very small, the insertion of a spring of hoop iron is sufficient (*a spring chaplet*), O. Similarly light double-faced chaplets, M, N, are often used for the same purpose without any anchorage.

In thin castings, notably in pipes, the risk of the metal not melting the chaplet sufficiently, and so causing leakage, is met by increasing the metal around it. The moulder makes a convex boss-like impression in the mould, L, with the aid of his trowel handle, so giving the extra thickness, which more than compensates for that occupied by the plated portion of the chaplet.

P is a shell chaplet, shown in use at Q. Being made in uniform dimensions, these serve to centre cores accurately, and provide a steadying effect also. The molten metal flows inside the shell, securing perfect amalgamation with the casting, the vent hole at the top permitting the gas to escape.

Charcoal.—An amorphous form of carbon obtained by the destructive distillation of organic substances. The name is commonly used only to denote wood charcoal; the form obtained by charring bones is called **Animal Charcoal**; and the sooty deposit obtained by the imperfect combustion of oils and tallow is called lamp-black.

Wood charcoal is obtained by building up a conical heap of billets of wood, leaving a hollow space to act as a flue down the centre, and holes at the base, the whole being then covered with turf or moist ash. Lighted wood is fed through the opening in the top for several days, and when this "smothered" combustion is complete, the heap is left to cool, the resultant charcoal consisting of about 24 per cent. by weight, and 63 per cent. by measure of the wood used. Charcoal for the manufacture of gunpowder is obtained by heating the wood in externally heated cylinders to avoid the presence of grit.

In addition to its use as a fuel and for gunpowder, charcoal is largely used in a finely

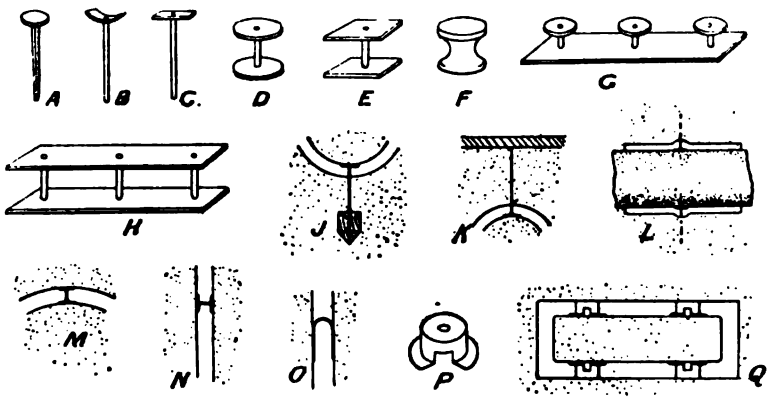


Fig. 173.—Chaplets.

ground state as a deodorant, owing to its power of absorbing and oxidising offensive gases. Hence its value in hospital wards, in filters, and the ventilating of shafts of sewers. Its decolourising property also renders it valuable in many commercial processes as in the decolourising of syrups in sugar refining, mentioned under **Animal Charcoal**. Owing to its poor conductivity, charcoal is also used for surrounding cold storage chambers. The surface charring of piles, posts, and poles is done to arrest decay.

Charcoal is the best fuel for smelting iron ores, for which purpose it has been employed from time immemorial; the use of pit coal and coke are comparatively modern innovations

Small quantities of very pure iron are still produced by the old processes now. Charcoal is used in cementation processes, in the foundry for the facings of moulds, for making small drying fires, for brazing joints, and other purposes.

Charcoal has a sp. gr. of about ·22, its buoyancy being explained by the presence of air in the pores.

Charcoal Blacking.—Moulders' blacking, prepared by grinding wood charcoal to fine powder in a roller mill. It is used dry, dusted on from a blacking bag, or made into a solution with water, and applied as wet blacking to be dried subsequently.

Charcoal Iron.—Pure qualities of malleable iron refined in furnaces using charcoal. The steel industry has largely displaced these, notably in tin plate manufacture.

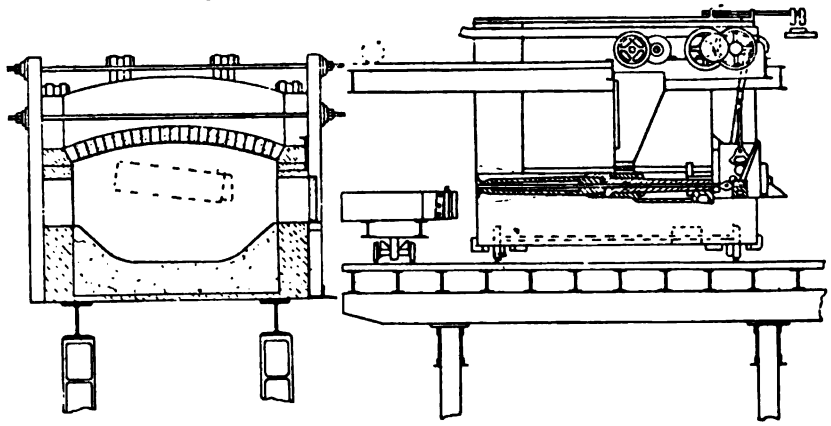


Fig. 174.—Wellman Electric Open Hearth "High Type" Charging Machine.

Chargeman.—A workman who has charge of a gang of men employed on a large piece of work. Corresponds with a leading hand, or ganger, or sub-foreman.

Charging Box.—A steel box built to carry materials for open hearth furnaces. The body is of steel plate, the end which receives the ram of the charging machine is a steel casting recessed to receive the T end of the ram.

Charging Machines.—Charging machines as applied to steel manufacture may be divided broadly into two classes, viz., open hearth furnace charging machines, and re-heating furnace charging machines. The first named is used for introducing the necessary materials into the Siemens-Martin furnace, whilst the duty of the second is to feed ingots, blooms, and slabs into re-heating furnaces, or to charge and discharge soaking pits. Both classes of machines have developed in three distinct forms, the high type, the low type, both operated from the floor; and the overhead type operating upon an elevated runway in a similar manner to an ordinary traveller.

Dealing first with open hearth chargers, the usual *modus operandi* is to bring the materials to the front of the furnace in boxes carried upon bogies running upon rails; the charging bar of the machine is then moved forward, engages with a box of material, and is locked thereto, the box is then lifted, carried into the furnace, turned over to empty, and withdrawn. The complete cycle of operations is under the control of one man located upon the machine; several boxes are carried upon one bogie, and as they are emptied in turn, the machine acts as a locomotive and shunts the line of bogies so as to bring a full set of boxes in front of the furnace door. In the overhead type of machine a revolving motion is sometimes fitted in cases where it is not convenient to bring the bogie track between the charger and the furnace; by such provision the machine can pick up the boxes from any track arranged within its scope of action. Open hearth chargers are invariably electrically driven, a separate motor being fitted to each motion.

Coming to re-heating furnace chargers, a variety of forms are in evidence; the particular

construction and method of operation depending upon the arrangement of furnace and upon the class of ingot to be manipulated. A common type of machine receives an ingot from a crane, and simply pushes it into the furnace. Such machines are of the ground type, and have

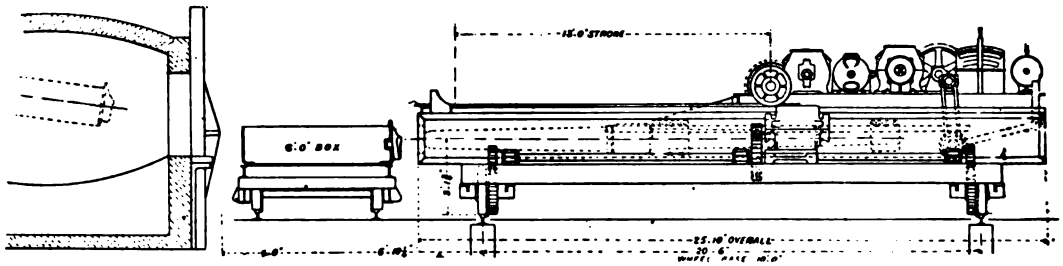


Fig. 175.—Wellman Standard Low Type Open Hearth Charger.

locomotive gear fitted, together with revolving, and sometimes elevating, gear; they are operated by steam, electricity, and occasionally by hydraulic power. Another, and a more modern type of charger, has appliances for gripping the ingot, and is therefore enabled to withdraw an ingot from the furnace as well as to pick it up without the intervention of a crane; such machines are made to serve both horizontal and vertical furnaces, they are invariably elec-

It comprises a steel framing mounted on four wheels, two of which are geared to an electric motor. The framework supports four steel columns, which carry two beams that project towards the furnace, and over the track on which the charging cars travel. These beams carry tracks on which a trolley traverses, having at its front end supports for the charging bar. The latter is carried on trunnions located at about the centre of its length, which permit the front end of the bar to be raised and lowered. The front end (made removable in case of accident) is of T shape to fit a recess in the back of the charging box. The operator's cab is at the back of the charging bar. This contains the electric controllers, a motor for

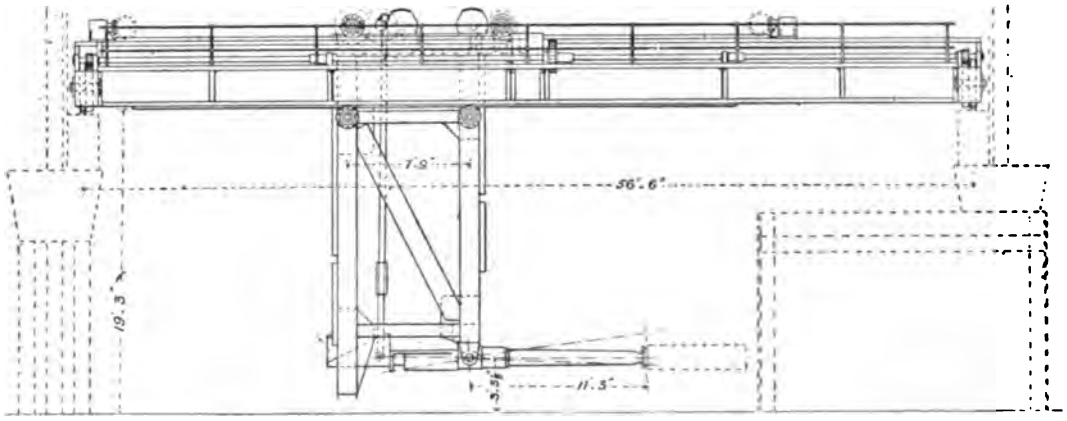


Fig. 176.—Wellman Standard Overhead Type of Open Hearth Charger.

trically driven, and are largely manufactured as overhead type machines, and it is in this latter form that they displace ingot cranes in the working of soaking pits.

Coming to details; the high type machine, Fig. 174, which gives more floor space than the low type, is a favourite form, and is built as follows:—

turning the ram, and a lever for locking the charging box to the ram. The motor is connected by a train of gears to a crank shaft, by means of which through connecting rods the end of the charging bar is raised and lowered. A motor at the farther end of the carriage effects the cross traverse, driving through a

single reduction gear to the forward axle. The action of the machine can now be understood :—

The train of charging boxes being brought on rails in front of furnaces, the charging machine is run along by its longitudinal traverse motor opposite the box to be charged. The lifting motor then lifts the operator's cab and back end of charging bar (on the trunnions), thus lowering the front end of the bar until the tee end of the charging bar engages the recess at the back end of the charging box, which is then locked by the operator, by means of a long rod passing through the charging bar, the front end of this rod entering a corresponding hole in the casting at the end of the bar. The lifting motor is now reversed, lowering the cab, and raising the box at the front end. The cross traverse motor now runs the box into the furnace, and its ram is rotated by the motor in the cab, so turning over the box, and discharging its contents. It is then run back and reversed, and deposited on the car, and the next box taken.

The mechanism of the low type machine, Fig. 175, resembles that just described, but the frame on which the trolley travels is near the floor. It is not so much in use as the other, as it requires a wider platform, but it is suitable for open hearth furnaces which are partially charged with hot metal, as a ladle crane has room to operate over it.

In the overhead or crane type of machine, Fig. 176, the charging mechanism is suspended from the trolley of an overhead travelling crane. Floor tracks being dispensed with, leave the ground area clear. Existing traveller runways can be utilised. A machine may have a double charging bar to serve a double row of furnaces, but the revolving overhead type is generally preferred. All types running overhead can be fitted with an auxiliary hoist to be used for regular hoisting work, as the elevating of charging boxes and materials from a lower level to the charging platform.

Similar types of machines are built to serve re-heating furnaces, handling ingots, blooms, slabs, &c., instead of charging boxes. Details are varied to suit requirements, but the broad divisions of high, low, and overhead crane types are retained. There are two leading sub-types of the last named. One has a rotating or turn-table device which enables the charger to serve furnaces on both sides of the shop, Fig. 177, and the tongs can be turned to any point, so that ingots can be deposited on slabs or roll tables wherever situated. The other type is suitable for serving a single row of furnaces, picking up the ingot slab from, and replacing it on cars, or live rolls, which latter run parallel to the charging machine's own cross travel, Fig. 178. *See also* photos, Plates XIV. and XV., Figs. 179, 180, 181.

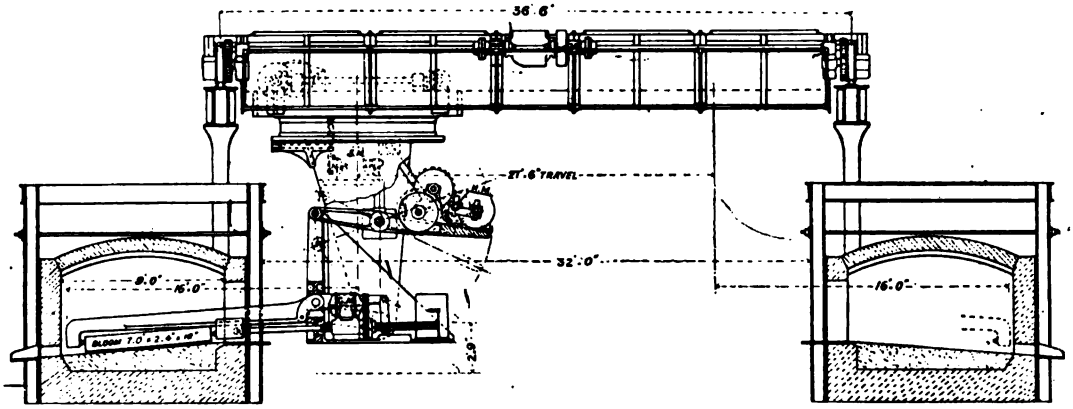


Fig. 177.—Wellman Standard Overhead Type of Revolving Bloom Charger.

Charles' Law.—Sometimes termed Gay-Lussac's Law, deals with the expansion of gases by heat; and if pressure be constant the relation between temperature and volume may be stated thus :—The volume of any gas at constant pressure expands when heated, by the same fraction of itself. *See* **Gases.**



Fig. 179.—Open-Hearth Charger at British Westinghouse Works, Manchester. (Wellman-Seaver-Morgan Co., Ltd.)

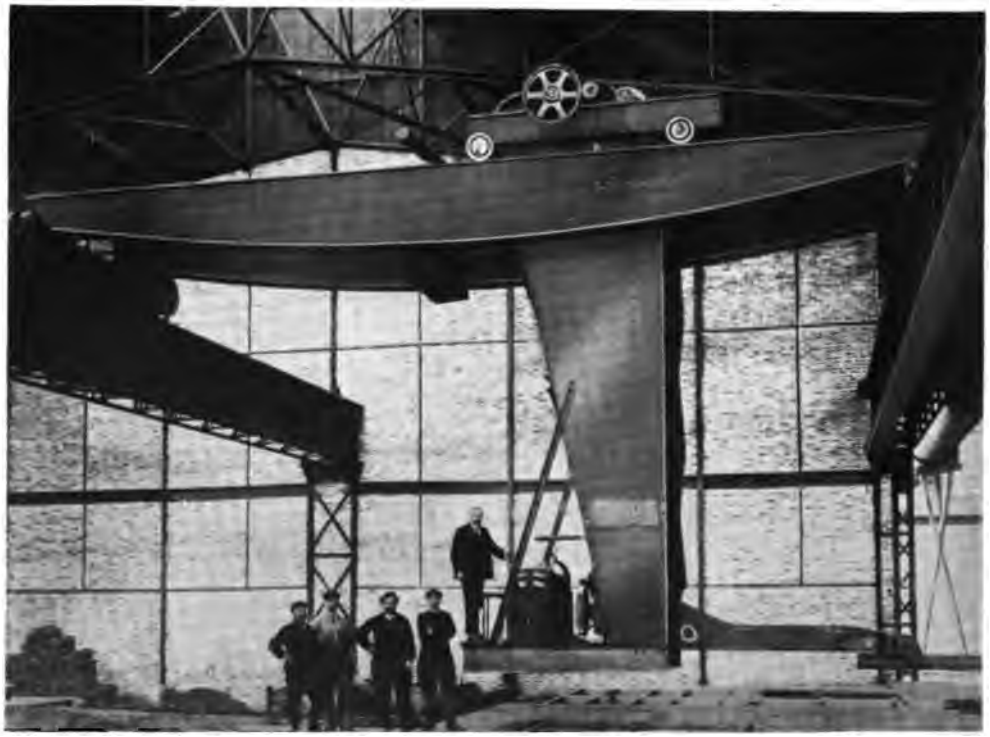


Fig. 180.—Bloom Charging Machine at Compagnie des Forges de Chatillon Commentry et Neuves Maison, France. (Wellman-Seaver-Morgan Co., Ltd.)

To face page 214.

Chaser, or Chasing Tool.—Also termed Comb Tool, and employed either as a formative or a finishing method of cutting screw threads. In the Chasing Lathe, the tool is carried in the traversing slide rest, and moved along by the master or "leader" screw, and in hand work the chaser is gripped in the workman's hand, and helped along as the work rotates. The former type are made with plain shanks for clamping with the rest screws, the latter with tangs for handling by, similarly to files. The cutting teeth, which are shaped to match the screw threads, and backed or cleared off, average about six in number. External tools have the teeth straight across the end; internal ones parallel with the shank, on an offset or slightly cranked portion.

A large amount of hand chasing is done on certain classes of work, especially in brass. Correct pitching of thread and freedom from "drunkenness" is a matter for practice, depending on the correct ratio of traverse to speed of revolution. The mere reduction of screws already cut by slide rest or dies is a much simpler matter, and is a common method of obtaining very accurate fits between nut and screw, one cut after another being taken, trying the pieces together repeatedly, until the desired effect is attained. The term Screw Tools is commonly applied to Chasers; the separate cutters in Die-Heads are also called Chasers.

Chasing Lathe.—A special design, intended primarily for the repetition production of screw threads on various classes of work, especially brass fittings. The tools are carried in a rest which is traversed along by a "leader" or guide screw, generally of short length, and which can be removed for the substitution of other different pitches. Fig. 182 is an example containing all the essential elements of a chasing lathe, the details of which are widely varied according to size and use in other cases. The backgeared head A drives the leader or hob at the rear, and a segment nut engages with the threads—the nut being fastened to the bar B, so that the latter is traversed endwise as the hob rotates. Rest C is clamped to B, so partaking of its motion, and travelling the chasing tool over the work. Taper threads are produced by the adjustable bar D at the front of the bed, coercing the small roller *a* on the end of C. A flat-topped rest E is provided for use with hand tools of various kinds. The turret F, mounted on compound slides, enables other operations to be performed on the work, in the way of boring, turning, facing, &c. A

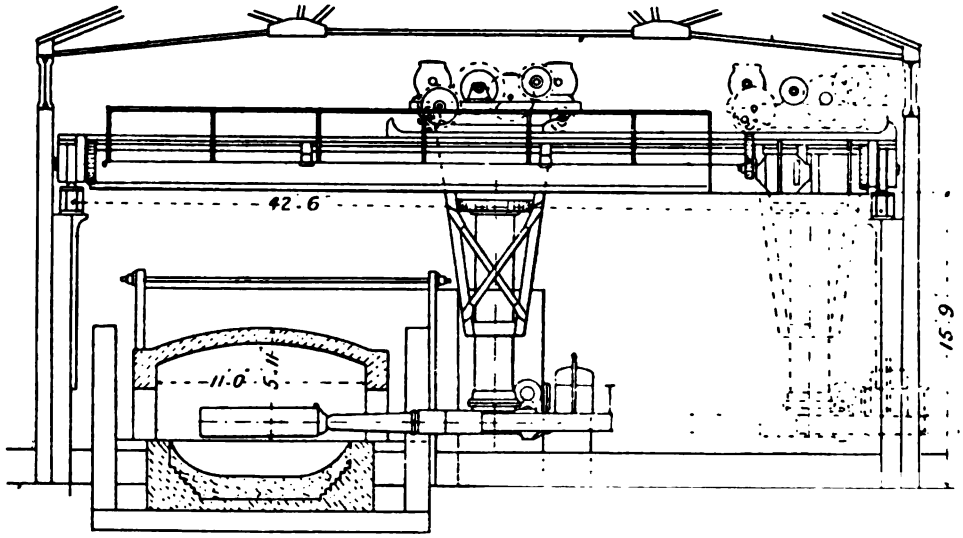


Fig. 178.—Wellman Open Hearth Charging Machine, Overhead Revolving Type.

friction backgear is alternatively fitted to the headstock, for changing without stopping the spindle. A detail which saves time consists in making the hob nut of star form, having several segmental threads of different pitch cut around the periphery, so that any one can be slewed round and locked to engage with the particular hob in use.

A somewhat similar design, but having a special driving device, is shown in Fig. 183, Plate XV. For ordinary turning and boring the spindle is driven by the three-stepped cones, but for tapping, the two-stepped cone is used, driving the shaft seen under the head cones. At the end of this a small friction disc is backgear is fitted. A device is provided so that as the tool is thrown into the work the nut simultaneously engages with the leader, and *vice versa*. The other details of the lathe much resemble those of the Capstan Lathe shown on page 141. The term Chasing Lathe is also applied to that type having a die-head running over the work, with flat steel cutters. *See* **Open-Spindle Capstan Lathe.**

Chatter.—Rapid vibration, minute in amount, but apparent in the ribbing of the surface of work being tooled by turning, boring, planing, shaping, milling, &c. The causes of this evil are mainly due to machine framings, spindles, and tools being too light for the duty imposed on them.

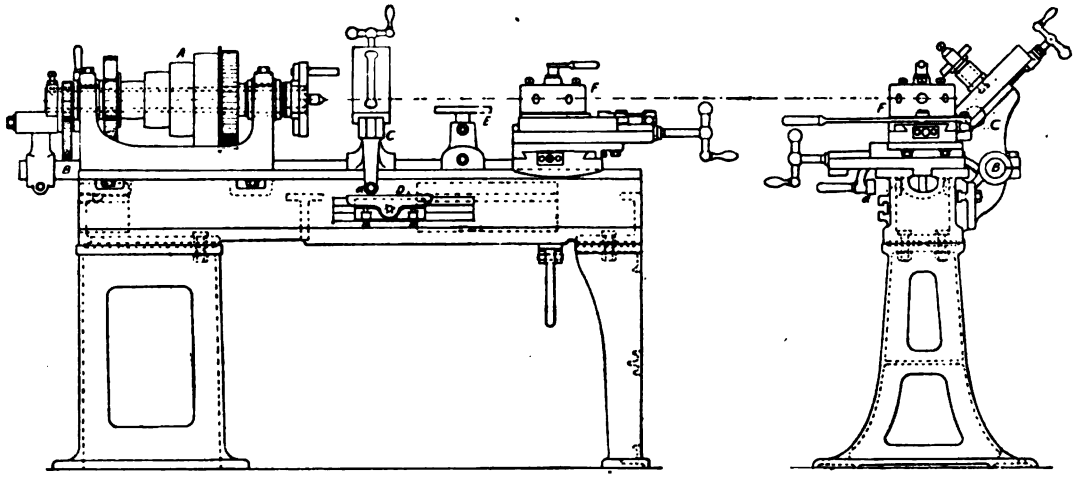


Fig. 182.—8½-inch centre Chasing Lathe. (Webster & Bennett.)

fastened, and, by the long lever seen in front of the bed, can be thrown into contact with either the outer internal rim of the large disc seen, or the smaller periphery within. In one case, the slow speed, tapping is done, in the other, fast speed, withdrawal is effected rapidly.

Another style of chasing lathe, with the hob in front of the bed, is seen in Fig. 184, Plate XV. The chasing saddle (resembling a cross slide somewhat) is travelled along by a nut engaging with this hob, which is removable, for effecting changes. Each leader may be driven at four different rates, to cut four pitches without alteration, this being effected by the change gear box to the left. Friction

The remedy therefore is either to stiffen up design, or to reduce feeds. Increased lubrication in some cases lessens chatter. Also, when practicable, imparting support to the work opposite the tool will often prevent or lessen chatter.

Check.—Shouldered portions projecting and recessed respectively to fit each other. They are used either when objects have to be centred without any tentative adjustments, or when the check affords security which would not be available with plain faces. Loam moulds illustrate examples of the first named, and cylinder covers and heavy hydraulic pipe flanges examples of the second. In these last cases the bolts are relieved of shearing strain.



Fig. 181.—Electric Charging Machine for Siemens-Martin Furnace.
(Ludwig Stuckenholz, Wetter-on-Ruhr, Westphalia.)



Fig. 183.—Chasing Lathe. (Webster & Bennett.)

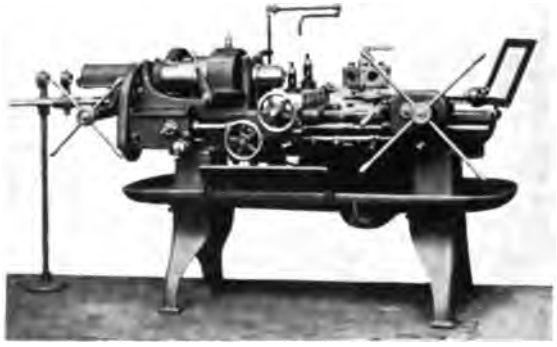


Fig. 184.—Chasing Lathe. (A. Herbert, Ltd.)



Fig. 195.—Circular Milling Machine.
(Ludwig Loewe & Co.)



Fig. 196.—Circular Milling on Cincinnati Machine, Using Rotary Table.

To face page 216.

Check Nut.—*See* **Lock Nut.**

Check Rail.—A rail sometimes put within the inner side of the inner rail of a curve to prevent the wheels mounting the outer rail.

Check System.—In this system, so long in use, metal discs, the men's *checks*, are each stamped with a number, allocated to one man, and hung on a board outside the time office, or inside if the men pass through it. Each one on entering, takes off his check and deposits it in a box; these are collected by the timekeeper before the next entry of the men, and the numbers, taken from the checks, are duly posted up in the time book as being "in." Then the checks are all hung up in their places on the board by the timekeeper for the next entry. If any men go out after or before the regular hour, their time of exit is entered by the timekeeper opposite their numbers in the time book.

This system has answered very well, but it gives no exact record of time, and has to be supplemented by the clerical work of the gatekeeper. It is therefore being very generally displaced by **Time Recorders,** supplemented by a **Card System.**

Check Valve.—A valve fitted in the course of a steam or water supply to prevent the return of the fluid or liquid. Thus, in pumping water into a steam boiler some portions of the water would return through the valve, but for the closing of the non-return or check valve. These are made both in straight-way, and in right-angle patterns, and with flanges, or screwed ends. An alarm check valve is one so designed that if an injector does not work properly the valve will close and the steam will escape by a small valve, and so call attention to the fact.

Cheeks.—A term which signifies in general the sides or side frames of cranes, and other mechanisms which afford support to shaft bearings. They are made of cast iron, and are also plated. Examples will be seen in the numerous cranes in these volumes.

Cheese Head.—Denotes the circular head of a screw which is parallel, and which is often sunk below the surface of the work.

Chemistry.—Among the many branches of science of which the modern engineer should have at least an elementary knowledge, chemistry takes a leading place. For a history of the progress of chemistry, for a discussion of principles and theories, and an exhaustive treatment of the properties, chemical action, and application of the elements and compounds, reference must of course be made to the text-books. But scattered throughout these volumes are many articles dealing with the chemistry of those solids, liquids, and gases with which engineering is peculiarly concerned, and the purpose of this article is rather to deal with the elementary principles, and to explain the facts and the chemical symbols, formulæ, and equations that occur in this work. Thus the following paragraphs will prove useful to the student whose knowledge of chemistry has grown "rusty," and render equations and formulæ, &c., intelligible to those ignorant of the subject.

A clear idea of what is meant by *chemical action* is necessary. If a piece of platinum wire be heated in a flame it immediately acquires new qualities, for it gives off heat, and to some extent light. When, however, the wire is removed from the flame, those qualities vanish as rapidly as they were acquired. If a strip of magnesium wire be similarly placed in a flame, heat and brilliant light are produced, but the ribbon has undergone a very different change to the platinum wire. The platinum remained platinum, and its newly acquired properties were but temporary; the magnesium became changed into a totally different substance lacking the original properties of the wire and possessing others, and the change was permanent. The permanent change in the case of the magnesium is a *chemical change*, and the temporary change in the platinum is a *physical change*. Or, again, a piece of wrought iron may be magnetised and it is still wrought iron, but if a portion be reduced to filings, and these be mixed with sulphur and heated, a chemical change has taken place, for a totally new substance is formed, different in appearance and properties.

By the study of chemical action on the countless forms of solid, liquid, and gaseous substances, chemists have succeeded in breaking up all forms of matter surrounding us into

seventy-eight kinds that cannot, by any means at our command, be broken up into anything simpler. These have therefore been called *elements*, but in the light of recent research the meaning originally attached to the word must be rejected. The elements are in reality compound forms of matter, and can only be considered as elementary in the sense that we are at present unable to reduce them to any simpler form. It is quite likely that this list of elements will be extended—the discovery of radium, argon, helium, krypton, neon, and xenon, is within the memory of every one. As regards the distribution of these elements, they all occur in the earth, some thirty in the sea, and about nine in the atmosphere; and in proportion, oxygen monopolises about 50 per cent. of the earth's crust, silicon 25 per cent., aluminium 8 per cent., iron 5 per cent., calcium, magnesium, sodium, and potassium from 1 to 4 per cent., while all the other elements exist only in minute quantities. By far the greater majority of the elements occur in combination with others. Some, however, occur in a free state, the most important of these being oxygen, nitrogen, copper, silver, sulphur and carbon. A chemical combination of these elements (such as that of the iron and sulphur mentioned in the previous paragraph) is called a *compound*.

A complete list of all the elements known is given below with their symbols, and in Mendeleeff's Table, on the next page, with their atomic weights, as sanctioned by the International Committee on Atomic Weights in 1905. The elements are classed as *metals* and *non-metals* (or metalloids), but the division is almost purely arbitrary. The lustre, malleability, brittleness, weight, and so on, that the engineer of all men associates with a metal, are not necessarily present in some of these "metals." Thus we find mercury to be liquid, lithium is the lightest solid in existence (sp. gr. = ·59; water = 1), sodium can be easily cut with a knife, and potassium squeezed between the fingers, while each is lighter than water. Many of the "non-metals" possess the metallic lustre usually associated with metals.

Aluminium Al, Antimony Sb, *Argon A*, *Arsenic As*, Barium Ba, Bismuth Bi, *Boron B*, *Bromine Br*, Cadmium Cd, Caesium Cs, Calcium Ca, *Carbon C*, Cerium Ce, *Chlorine Cl*, Chromium Cr, Cobalt Co, Columbium or Niobium Cb, Copper Cu, Erbium E, *Fluorine F*, Gadolinum Gd, Gallium Ga, Germanium Ge, Glucinum or Beryllium Gl, Gold Au, *Helium He*, *Hydrogen H*, Indium In, *Iodine I*, Iridium Ir, Iron Fe, *Krypton Kr*, Lanthanum La, Lead Pb, Lithium Li, Magnesium Mg, Manganese Mn, Mercury Hg, Molybdenum Mo, Neodymium Nd, *Neon Ne*, Nickel Ni, *Nitrogen N*, Osmium Os, *Oxygen O*, Palladium Pd, *Phosphorus P*, Platinum Pt, Potassium K, Praseodymium Pr, Radium Ra, Rhodium Rh, Rubidium Rb, Ruthenium Ru, Samarium Sm, Scandium Sc, *Selenium Se*, *Silicon Si*, Silver Ag, Sodium Na, Strontium Sr, *Sulphur S*, Tantalum Ta, *Tellurium Te*, Terbium Tb, Thallium Tl, Thorium Th, Thulium Tm, Tin Sn, Titanium Ti, Tungsten W, Uranium U, Vanadium V, *Xenon Xe*, Ytterbium Yb, Yttrium Yt, Zinc Zn, Zirconium Zr.

In this table the so-called non-metals are printed in italics, but it must be remembered that this classification is now of little more than historic interest. The only rational grouping is that based on the somewhat startling *Periodic Law* discovered by John Newlands, and developed by Russia's great chemist, Mendeleeff. It had been remarked that by taking the atomic weights of elements with similar properties, such as calcium, strontium, and barium in the calcium group of metals, or magnesium, zinc, and cadmium in the zinc group, that the atomic weight of the second element was obtained by simply finding the mean between the first and last. (The atomic weight of an element represents its weight when, in the state of a gas, and under similar conditions of temperature and pressure, it occupies the same volume as one part by weight of hydrogen.) Thus the atomic weight of calcium = 40·1; barium = 137·4 and $\frac{40{\cdot}1 + 137{\cdot}4}{2} = 88{\cdot}7$, which is remarkably near the atomic weight of strontium, 87·6. Mendeleeff arranged the elements as in the following table in the order of their atomic weight, beginning with hydrogen, so that they formed eight groups and twelve series. Harmony and order immediately sprang out of chaos.

THE ELEMENTS GROUPED ACCORDING TO THE PERIODIC SYSTEM.

Group	1	2	3	4	5	6	7	8
Series 1	H 1	...	...	...	...	...	...	
2	Li 7·03	Gl 9·1	B 11	C 12	N 14·04	O 16	F 19	
3	Na 23·05	Mg 24·36	Al 27·1	Si 28·4	P 31	S 32·06	Cl 35·45	
4	K 39·15	Ca 40·1	Sc 44·1	Ti 48·1	V 51·2	Cr 52·1	Mn 55	Fe 55·9, Ni 58·7, Co 59
5	Cu 63·6	Zn 65·4	Ga 70	Ge 72·5	As 75	Se 79·2	Br 79·96	
6	Rb 85·5	Sr 87·6	Yt 89	Zr 90·6	Cb 94	Mo 96	...	Ru 101·7, Rh 103, Pd 106·5
7	Ag 107·93	Cd 112.4	In 115	Sn 119	Sb 120·2	Te 127·6	I 126·97	
8	Cs 132·9	Ba 137·4	La 138·9	Ce 140·25	...	...	...	
9	...	...	...	...	...	...	...	
10	...	...	...	...	Ta 183	W 184	...	Os 191, Ir 193, Pt 194·8
11	Au 197·2	Hg 200	Tl 204·1	Pb 206·9	Bi 208·5	...	...	
12	...	Ra 225	...	Th 232·5	...	U 238·5	...	

All the members in any particular group possess wonderfully similar physical and chemical properties, those on the left of each column being more analogous than those on the right. Stranger still, in the horizontal series there is a regular gradation of properties, physical and chemical—in specific gravity, in the number of atoms of oxygen and hydrogen with which each element combines, in electro-positive and negative properties, and in many other respects. It thus appears that the *properties of the elements are periodic functions of their atomic weights*, and by a study of these cycles of recurring properties it is possible not only to correct atomic weights of known elements, but where gaps occur, to predict the discovery of new elements, and to foretell their atomic weights and physical and chemical properties! As a matter of fact this was actually done by Mendeleeff in the case of gallium, scandium, and germanium, and in the fulness of time they were discovered. The gaps in the present table indicate the possible existence of unknown elements, while the position in this table of some of the newly discovered elements is somewhat uncertain, and therefore they are omitted.

The inferences we are compelled to draw from this periodic law shatter early conceptions. We can no longer regard these seventy-eight elements as distinct forms of matter to be pigeon-holed as metals or non-metals according to a chance analogy of qualities, but as a connected whole, each and all being forms of *one* element. We are therefore thrown back on the atom, and compelled to regard it no longer as indivisible. There must be something yet more elementary, some unit which is able to combine with similar units in varying ways, so as to form atoms of what we now regard as different elements.

The atomic theory supplied the science of chemistry with a kind of chemical shorthand, which enables us to show by a few letters and figures both the *qualitative* and *quantitative* composition of any substance. Each element is denoted by a *symbol*, which may be the initial of its name, as C for carbon, or the initial and another letter, as Cl for chlorine, Pb for lead (Lat. *plumbum*), and so on. But in addition to representing a particular element the symbol also denotes a certain relative quantity of that element; H always denotes 1 part by weight of hydrogen, C 12 parts of carbon, Fe 55·9 parts of iron, Sn 119 parts of tin, these numbers being their atomic weights or combining proportions compared with hydrogen as unity. When two or more elements are chemically combined the compound is represented by a *formula* made up of the symbols

of each element concerned. Thus a combination of sodium (Na) and chlorine (Cl) produces sodium chloride or common salt, which is represented by NaCl, this formula denoting that 23·05 parts (say grammes) of sodium united with 35·45 grammes of chlorine give 58·50 grammes of sodium chloride. Where a multiple of an element occurs it is represented by a small figure placed after the symbol, as $H_2O = 2 \times 1 =$ 2 parts of hydrogen + 16 parts of oxygen = 18 parts of water. But if the numeral is prefixed to a compound or a bracketed group of elements in a compound which act as a single element and form a compound radical, it multiplies the whole group that follows it, as in $2HCl$; $2CH_2O_2$; $3(NH_4)_2SO_4$. The great value of this system of chemical notation is seen when it is desired to represent chemical changes. The formulæ are then set out in the form of an equation. The action of hydrochloric acid on zinc is represented as follows:—$Zn + 2HCl = ZnCl_2 + H_2$, which means that 65·4 grammes of zinc and $2\ (1 + 35{\cdot}45) = 72{\cdot}9$ grammes of hydrochloric acid yield $(65{\cdot}4 + 2 \times 35{\cdot}45) = 136{\cdot}3$ grammes of zinc chloride and $(2 \times 1) = 2$ grammes of hydrogen. By adding up the quantities on each side of the equation it will be observed that the total weight of the products equals the total weight of the substances taken. Thus in chemical processes it is possible to calculate how much of each substance must be taken to yield given quantities of the solids, liquids, or gases which result from chemical action.

The conditions under which chemical action takes place, the manner in which it occurs, and the laws it obeys are dealt with under **Action, Chemical.**

The *valency*, *atomicity*, or *quantivalence* of an element is its combining capacity. The elements do not always combine atom for atom. On comparing the four compounds, HCl, H_2O, NH_3, and CH_4, it will be seen that in HCl 1 atom of chlorine combines with 1 atom of hydrogen; in H_2O, 1 atom of oxygen combines with 2 atoms of hydrogen; in NH_3 1 atom of nitrogen combines with 3 atoms of hydrogen; in CH_4 1 atom of carbon combines with 4 atoms of hydrogen. Therefore chlorine is said to be monovalent or a monad, oxygen is divalent or a dyad, nitrogen trivalent or a triad, carbon tetravalent or a tetrad, and so on. As few metals combine with hydrogen their valency is discovered by their combining capacity with chlorine. Some elements vary in their valency, chlorine being a monad in HClO, a triad in $HClO_2$, a pentad in $HClO_3$ and a heptad in $HClO_4$. (This will be seen by satisfying hydrogen—a monad, and oxygen—a dyad, in each formula.) The valency of an element is graphically represented by means of dashes or "bonds."

Cl–, –Cu–, $-\overset{|}{\underset{|}{Fe}}-$, $-\overset{|}{\underset{|}{\underset{|}{Sn}}}-$, &c. The composition of certain common substances would then be represented as follows: —

$$H\text{–}Cl,\ H\text{–}\overset{H}{\underset{H}{C}}\text{–}H,\ H\text{–}O\text{–}\overset{O}{\underset{O}{S}}\text{–}O\text{–}H,\ Ca{=}O,\ H\text{–}\overset{H}{N}\text{–}H.$$

All the elements (except fluorine) combine with oxygen forming *oxides*. In certain cases an element unites with oxygen in several proportions, as Co, Co_2, N_2O, NO, N_2O_3, N_2O_4, N_2O_5. The various oxides are then denoted by the Greek prefixes:—*mon*oxide, *di*oxide, *tri*-oxide, *tet*roxide, *pent*oxide. If, as in Al_2O_3 and Fe_2O_3, the ratio is as 2 : 3 the term *sesqui*oxide is used (Lat. *sesqui* = one-half more). A *base* is an oxide (generally of a metal), which yields a **Salt** when acted on by an **Acid**, as:—

$$Fe_2O_3 + 6HCl = 2FeCl_3 + 3H_2O.$$
$$\text{oxide} + \text{acid} = \text{salt} + \text{water}.$$

Oxides in combination with water are called *hydroxides* or *hydrated oxides*, as KOH, potassium hydroxide, $Ca(HO)_2$ calcium hydroxide. These also form salts in neutralising acids. Oxides which unite with water to form acids are *anhydrides*.

An element is said to be in a *nascent state* at the moment of its liberation from a compound. It is then unusually active, as in the example given under **Chlorine** where the oxygen liberated (when Cl unites with H) possesses remarkable bleaching properties:—$Cl_2 + H_2O = 2HCl + O$. This may be explained by the fact that the newly liberated atom is as it were unrestrained in its choice of a partner, but once it is united with others to form a molecule its freedom of choice is taken from it, or only exists in a limited degree.

Oxidising and *reducing* agents are those capable respectively of adding oxygen to or taking it away from any substance. An example of the first is seen in the oxidation of the carbon, silicon, &c., of pig iron in the manufacture of **Bessemer Steel**; of the second in the reduction of the iron ore during its descent in the **Blast Furnace**.

Deliquescent salts are those which attract moisture from the air and so become liquefied. Zinc chloride, $ZnCl_2$, and calcium chloride, $CaCl_2$, are extremely deliquescent. This property is obviously useful in drying gases, salts, &c.

Electrolysis means the decomposition of a compound by means of an electric current. Solutions of acids, salts, and alkalis in water, alcohol, or other solvent, allow the passage of an electric current, and the products are given off at the positive and negative poles. The electrolytic decomposition of water is a familiar proof of both its qualitative and quantitative composition. The material decomposed is the *electrolyte*; the *electrodes* are the conductors by which the current enters (anode), and leaves (cathode), the solution; the *ions* are the product of the electrolysis.

An *inert* substance is one such as nitrogen, which not only does not combine readily with any other substance, but neither burns nor supports combustion.

Amorphous substances are those having no characteristic shape, as opposed to crystalline substances. Charcoal is amorphous, the diamond is crystalline, and here we have an example of **Allotropy**.

Osmose or *osmosis* is the interdiffusion of two liquids separated by a membrane such as a bladder or piece of parchment paper. The process illustrates the fact that different liquids diffuse with different degrees of rapidity.

Chequered Plates.—Foot plates of cast iron or sheet steel. In cast iron the chequers are of isolated diamond shapes. In steel they are continuous ribbings crossing at acute and obtuse angles, giving the diamond pattern. Cast-iron plates range from $\frac{1}{2}$ in. to $\frac{3}{4}$ in. thick, steel from $\frac{3}{16}$ in. to 1 in. These are rolled up to 20 ft. long and 52 in. wide. Their weights are given in lb. per square foot, thus $\frac{3}{16}$-in. plates weigh 9 lb. per square foot, while $\frac{1}{2}$-in. weigh $21\frac{1}{2}$ lb.

Chequer-Work.—Chequering or chequer-work consists of a mass of fire-brick built up dry in cellular form in an oven or chamber, so as to present a very large exposure of fire-brick surfaces to a flow of hot gas or of air. As employed in heating the blast of an iron furnace, waste furnace gas is first passed into the chamber or chequer-work stove and burned for some time, heating the brick-work to a high temperature. The gas is then diverted into a second similar oven, and the blast air is blown through the now heated chequer-work of the hot oven. Meantime the second oven is becoming hot, and when heated a change is again made in the flow of air and gas, and in this way the two ovens alternately obtain heat from the burning waste gases and give it up to the blast air. Similar regenerators are employed to heat the air for gas furnaces on the regenerative principle, the chequer-work ovens being alternately heated by the escaping gases of the furnace and cooled by the air passing on its way to the furnace. The principle is applicable in many directions. Each degree of temperature added to the air and gas before combustion causes an equal elevation of the temperature of combustion. Preferably the air regenerator is made larger than the gas regenerator, because the weight of air is greater than that of the gas it helps to burn. For continuous work hot gases escape in one direction along cellular passages, air flowing in the opposite direction along each alternate passage to the fire and carrying back to the fire some of the otherwise wasted heat. For moderately high temperatures regenerative effects may be obtained with cast-iron pipe stoves.

Cherry Red.—Denotes a colour for hardening most articles, preparatory to letting down, and also for certain bending and temper tests. The colour is supposed to be estimated in a dull light, as that of a shadow of a forge, or of a wall, on a dull day.

Cherry Wood.—Is a hardwood used for engineers' patterns. In some localities it is employed in preference to mahogany for the purpose. It is closer grained than mahogany, but resembles it very much in colour and appearance. It grows in most parts of the world, and is obtained in several varieties, but

it does not attain large dimensions, and consequently is only used for small work.

Chilled Wheels.—In the United States cast wheels are used generally for rolling stock; locomotive, tender, passenger, and freight cars. The webs are dished, and hollowed also around the boss; they are chilled, and it is this feature which renders annealing necessary. The mixing of the irons is therefore an important and sometimes difficult operation. They have to be altered frequently, and tests made. The chilled portion of the wheel of course sets almost immediately, and the wheels while red-hot are put into the annealing pits. If they were allowed to cool in the open air, severe internal strains would be created, which would rupture many of the castings. The period required for annealing varies from three to six days. The pits are cylindrical in shape, lined with brick-work, and contain about twenty wheels with cast-iron distance pieces between them. Designs vary, but essentially the operation consists in bringing heat from a furnace into the lower ends of the ovens, the heated gases pass off from the upper part into the chimney. The annealing is only such as is sufficient to prevent the too sudden cooling of the casting, so that the result is, that after the end of three days or so the castings have quite cooled down, and the wheels are removed. They are then tested by hammer blows, when frequently from 10 per cent. or more have to be rejected. The hardness of the rims requires a grinding wheel to effect the truing up, although the hub can be bored with ordinary tools. The average life of a chilled cast-iron wheel of first-class quality is said to be 50,000 miles for passenger, and 100,000 for goods traffic.

Chilling.—The art of producing a surface hardness in iron castings, while the interior portions retain the ordinary soft character of the metal.

Chilling is often popularly supposed to result from the mere contact of molten metal with the cold metallic surface of the chill. Conversely slow cooling is believed to have the opposite effect, that of softening a hard grade of iron. Both are right within narrow limits, but they do not cover the whole truth. It is not possible to chill all kinds of iron to any useful depth. Neither can all irons be softened by slow cooling.

An essential in irons for chilling is low silicon content, not exceeding 1 per cent. This follows from the fact that silicon throws out carbon in the form of graphite, and the presence of the latter would prevent chilling from taking place, for graphite iron will not chill to any sensible depth. The deeper the chill required, the less should be the amount of silicon present.

The iron used for chilling must be strong, because weak irons would break, due to the shrinkage strains in the inner metal set up by the firm setting of the outer chill. The chilled portion shrinks at once, and to the full amount, or more than the normal, but the interior continues to shrink, and the strain is liable to break weak irons. This explains why the discs of wheels of large diameter are frequently dished, or corrugated in section, so that they will yield without fracture. It also explains why a wheel with arms is not a proper design for chilling, the arms being liable to snap. The best iron for chilling is a very strong grey, or slightly mottled, but the composition can be varied much to suit the design and mass of the wheel, roll, shoe, bore, or other detail. Mass is the condition most favourable to chilling.

The depth of chill necessary depends on the purpose for which the casting is designed. An $\frac{1}{8}$ in. is sufficient on small work, as in the bores of wheel boxes, because before that is worn through, the fit would have become too slack; $\frac{1}{2}$ in. or more is not too much for heavy trolley wheels, and $\frac{3}{4}$ in. is not in excess. Rolls have as much as this. The shoes of battery stamps are chilled to from $\frac{1}{4}$ in. to $\frac{3}{8}$ in., plough points are practically all chill, since white iron is used for these, and the metal is thin.

The work of grading metal for chilling is one that calls for much experience, and disappointment sometimes results after every care has been taken. The important point is to have a strong iron that will stand the strain of chilling. An iron of unsuitable grade will not chill beyond a mere surface film of hardening. One which is suitable will show on fracture long silvery white crystals, radiating from the chilled

surface, while all within will be light grey, or mottled.

Chilling depends for its success on the suddenness of the cooling. It has been proved by experiment that graphite is separated not only at the moment of solidification of iron, but after it has become solid. This helps to explain the facts of sudden chilling, by which its separation is absolutely arrested.

Chill Moulds.—Moulds of cast iron made for casting chilled work in. Moulds, therefore, for this work are of a composite character, comprising the body of the mould of green or dried sand as usual, and the chill portion which corresponds only with the surfaces to be hardened.

Mass is essential in the body of the chill in order to enable it to resist fracture due to the sudden change in its temperature, and also to afford room for the rapid dissipation of the heat. All chills develop minute cracks on the surface which receives the metal, to a greater or less extent, with repeated casting into, which is another reason why mass is essential. From 6 in. to 8 in. of metal is required in a chill for an ordinary trolley wheel of 2 ft. or 2 ft. 6 in. diameter. And it has to be bonded also with wrought iron if risk of fracture is to be eliminated. A pattern is not necessarily made for a ring chill, but a segmental sweep only, which is worked round in the mould and covered with a plain top. After casting it is necessary to bore the interior, for rough-cast metal would not give a true surface to the chilled work, nor would the metal lay quietly against it. The polished surface is blackleaded before the metal is poured. The faces of the chill are also generally turned to insure correct thickness to the wheel or other article, and proper fitting of box parts.

A single example of chilled work will suffice to illustrate the method of operation.

A trolley wheel pattern is made as for ordinary moulding, and it fits within the chill, prepared as already stated. To avoid turning over the heavy chill, a common practice is to strickle the bottom part of the mould, using the ring chill as a guide to the strickle. Then the pattern is laid in, and the top box is rammed over it. Alternatively the ramming may be done on the bottom face, the bottom box being cottered to the chill, then turned over, and the top box similarly cottered and rammed.

Chimney.—A chimney is simply a form of heat engine which does work by reason of the difference in specific gravity of a column of air inside and outside the chimney. Its true function is thus to confine hot air in the form of a column up to such a height as shall enable the difference of specific gravity to produce a pressure effect, enough to cause a sufficient flow of air to the chimney through the resistance of a furnace and flues.

A furnace chimney and the atmosphere really form a closed system, the external cold atmosphere serving in effect as a condenser into which the chimney discharges hot gas, and whence the furnace accepts cold gas. The cycle might be closed by actual narrow bounding walls, but for the fact that the constantly circulating gases would cease to support combustion, and also that the chimney discharges a greater weight of gas than the furnace receives. Part of the work of the chimney is expended in lifting the additional weight of gas produced from the fuel.

Since air is about 800 times lighter than water, the pressure of a column of air per square foot is about $\frac{62{\cdot}5}{800} = 0{\cdot}08$ pound per foot of height, or 8 pounds per 100 feet of height. And since air at ordinary temperature has an absolute temperature of about 520° Fahr., and as the specific gravity of air varies with its absolute temperature, then air at 1040° absolute, or 581° Fahr., will have a specific gravity one-half that of air, at 520° absolute, or say 61° Fahr., and will exert a pressure of only 4 pounds per square foot per 100 ft. column. Then this 4 pounds would be the acting working pressure to produce movement. Since 1 foot of a column of water produces a pressure of 62·5 pounds per square foot, the effect of the 100 ft. chimney at the given temperature must be $4 \div 62{\cdot}5 \times 12$ inches of water column, or approximately $\frac{3}{4}$ inch of water. Experience shows that each quarter inch of draught water gauge at the base of a chimney will usually effect the combustion of 10 pounds of coal per square foot of grate per hour.

Since water weighs 62·4 lb. per cubic foot,

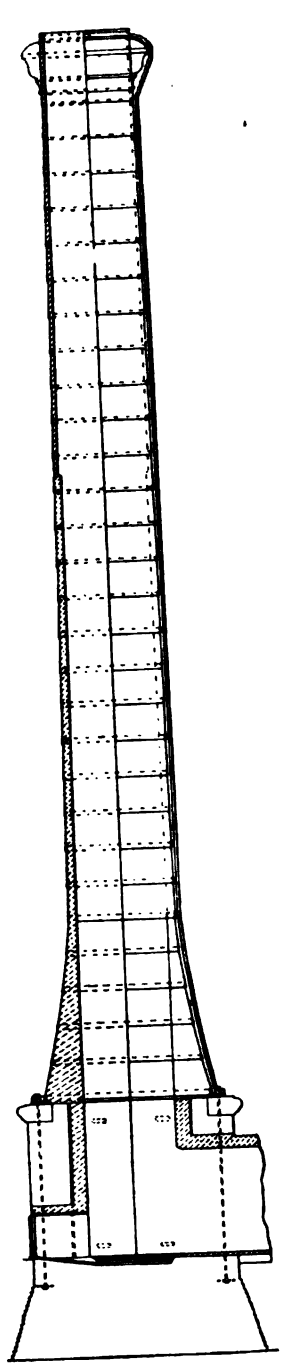


Fig. 185.—Chimney.

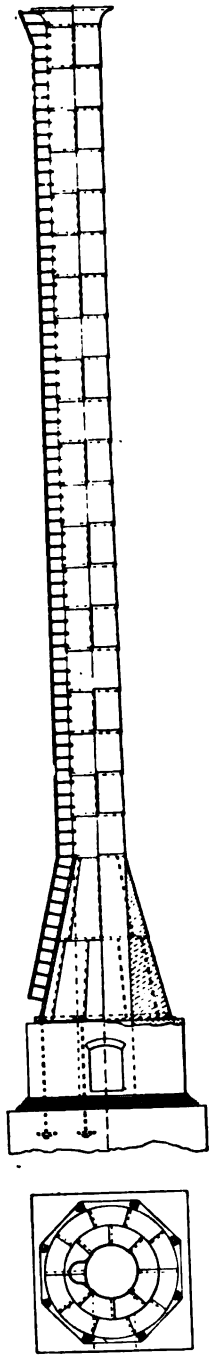


Fig. 186.—Chimney.

(Babcock & Wilcox, Ltd.)

and air about 0·077, the air column in feet equivalent to 1 inch of water is:—

$$h = \frac{62{\cdot}4}{12 \times 0{\cdot}077} = 67 \text{ ft.}$$

Since the velocity of flow per second of a fluid is $v = \sqrt{2gh}$, we have the velocity due to any head or water gauge $= v = 8\sqrt{67H}$, where H = inches of water gauge.

It is convenient to remember that where the ordinary formula for velocity of flow of water is $v = \sqrt{2gh}$, that due to a head expressed in inches of water column is almost exactly $v = 2g\sqrt{H}$. The following figures will be useful for finding the velocity of draught with any water pressure.

Inches of Water Gauge.	Velocity per second.	Inches of Water Gauge.	Velocity per second.
0·1	equals 20·7	0·7	equals 54·8
0·2	„ 29·3	0·8	„ 58·5
0·3	„ 35·8	0·9	„ 62·1
0·4	„ 41·4	1·0	„ 65·4
0·5	„ 46·3	2·0	„ 92·4
0·6	„ 50·7		

The efficiency of a chimney is very low. From 15 to 25 per cent. of the total heat of the fuel is carried off in the chimney gases, and is employed in raising a weight of gas of about 15 to 25 times the weight of fuel burned to the height of the chimney. Calculated out in foot pounds this result is a very fractional part of the mechanical equivalent of the heat expended.

Chimneys appear to be proportioned so that the rate of flow up them of the heated gases shall be from 20 to 30 feet per second. It is usual to line a chimney with fire-brick for a considerable height from the base, Fig. 185, this liner being entirely separate from the chimney, and standing freely inside it with an annular intervening narrow air space. Steel chimneys are often built for cheapness, Figs. 185, 186. They are internally lined with a ring of brick-work, and must be securely bolted down to a heavy foundation of wide-spread area as a security against wind pressure, Fig. 187.

SIZES OF CHIMNEYS WITH APPROPRIATE HORSE POWER OF BOILERS. (BABCOCK & WILCOX, LTD.)

Diameter in Inches.	Height of Chimneys and Commercial Horse Power.											Side of Square. Inches.	Effective Area Square ft.	Actual Area Square ft.
	50 ft.	60 ft.	70 ft.	80 ft.	90 ft.	100 ft.	110 ft.	125 ft.	150 ft.	175 ft.	200 ft.			
18	23	25	27	...	...	...	...	...	...	...	...	16	0·97	1·77
21	35	38	41	...	...	...	...	...	...	...	...	19	1·47	2·41
24	49	54	58	62	...	...	...	...	...	...	...	22	2·08	3·14
27	65	72	78	83	...	...	...	...	...	...	...	24	2·78	3·98
30	84	92	100	107	113	...	...	...	...	...	...	27	3·58	4·91
33	...	115	125	133	141	...	...	...	...	...	...	30	4·48	5·94
36	...	141	152	163	173	182	...	...	...	...	...	32	5·47	7·07
39	...	...	183	196	208	219	...	...	...	...	...	35	6·57	8·30
42	...	...	216	231	245	258	271	...	...	...	...	38	7·76	9·62
48	...	...	...	311	330	348	365	389	...	...	...	43	10·44	12·57
54	...	...	...	363	427	449	472	503	551	...	...	48	13·51	15·90
60	...	...	...	505	536	565	593	632	692	748	...	54	16·98	19·64
66	...	...	...	...	658	694	728	776	849	918	981	59	20·83	23·76
72	...	...	...	...	792	835	876	934	1,023	1,105	1,181	64	25·08	28·27
78	...	...	...	...	...	995	1,038	1,107	1,212	1,310	1,400	70	29·73	33·18
84	...	...	...	...	...	1,163	1,214	1,294	1,418	1,531	1,637	75	34·76	38·48
90	...	...	...	...	...	1,344	1,415	1,496	1,639	1,770	1,893	80	40·19	44·18
96	...	...	...	...	...	1,537	1,616	1,720	1,876	2,027	2,167	86	46·01	50·27
102	...	...	...	...	...	...	...	1,946	2,133	2,303	2,462	90	52·23	56·75
108	...	...	...	...	...	...	...	2,192	2,402	2,594	2,773	96	58·83	63·32
114	...	...	...	...	...	..	...	2,459	2,687	2,903	3,003	101	65·83	70·88
120	...	...	...	...	...	...	...	...	2,990	3,230	3,452	106	73·22	78·54
126	...	...	...	...	...	...	...	...	3,308	3,573	3,820	112	81·00	86·59
132	...	...	...	...	...	...	...	...	3,642	3,935	4,205	117	89·19	95·03
138	...	...	...	...	...	...	...	...	3,991	4,311	4,608	122	97·75	103·86
144	...	...	...	...	...	...	...	...	4,357	4,707	5,031	127	106·72	113·10

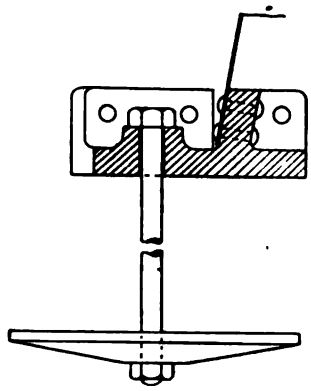


Fig. 187.—Foundation Plate and Bolt for Chimney.

China Ink.—Used in the drawing office owing to its permanency, its freedom from acid and consequent corrosion of steel points, its non-running qualities, and its extreme blackness. The best qualities are imported direct from China, and range in price from 1d. to 15s. per stick. It is the dried and compressed paste obtained from a mixture of extremely dense lamp-black, got by burning camphor or oils in a limited supply of air. It is rubbed from the stick with water, but as it becomes irregular and cloudy with keeping, liquid waterproof inks are widely used. If, however, the menstruum in which it is dissolved is not properly prepared, the carbon becomes gritty. Chinese ink is frequently but incorrectly called Indian ink, but sometimes a distinction is drawn between them—Indian ink drying dead black, and Chinese ink glossy.

Chinese Windlass.—The "wheel and axle," in which a load is hauled up by a cord around a small drum by a slight expenditure of power, pulling at a rope coiled round a large drum on the same axis. This mechanism occurs in several forms. The most practical is the **Differential Pulley Block**, in which two sheaves side by side are connected by an endless chain to a snatch block.

Chipping Chisel or **Cold Chisel.**—The chisel used by fitters and metal-workers generally, Fig. 188, A, for removing chips of metal by hammer blows dealt on the head of the chisel. It stands as the type upon which several modi-

fied forms are based. It is about an inch wide, and very slightly convex along the edge to enable it to penetrate better, and be more readily controlled than a tool quite straight would be.

A similar chisel, but narrower, ranging from ¼ inch to ½ inch in width is the cross cut, or cape chisel B, sometimes termed the keyway chisel, because that is one of its principal functions when hand work is concerned.

With these two tools, narrow and broad surfaces are cut. On large areas it is usual to run channels across with the cape chisel, leaving the outer areas to be removed with the ordinary one. This lessens labour, and is conducive to accuracy. Chipping when near an edge should not be done towards the edge, which might break out the metal, but the chisel should be directed inwards. Chisel cuts may cross and recross at different angles as the reduction proceeds. The value of these two tools is not so great as it was, because machining has largely displaced their old duties, but it is necessary to be adept in their use, especially in the case of heavy work in course of erection, which cannot be taken to machines, nor machines brought to it, notably in the fitting of castings to massive plated structures away from workshops. It is also of much value in repair jobs.

Forms derived from the foregoing are the cutting-off chisel, C, the round nose, D, E, and the cow-mouth, F. The first, C, is of prismatic form at the cutting edges (diamond-pointed). Its function is to run a nick or groove across a plate, or around a pipe which has to be severed by a sharp blow. The second, D, is used chiefly for cutting the narrow oil distributing grooves in shafts, on flat machine slides, and in concave bearings; for the last named purpose the back is generally curved longitudinally, E. It is only from ¼ in. to ⅜ in. wide. The cow-mouth, F, is like wood-workers' gouges, and ranging from ½ in. to 1 in. wide, is employed for chipping in concave surfaces. G is a chisel for cutting corrugated sheet, fitting the curve. H is a stone mason's chisel, made in many different proportions of length and breadth, and J is a plugging chisel for brick-work.

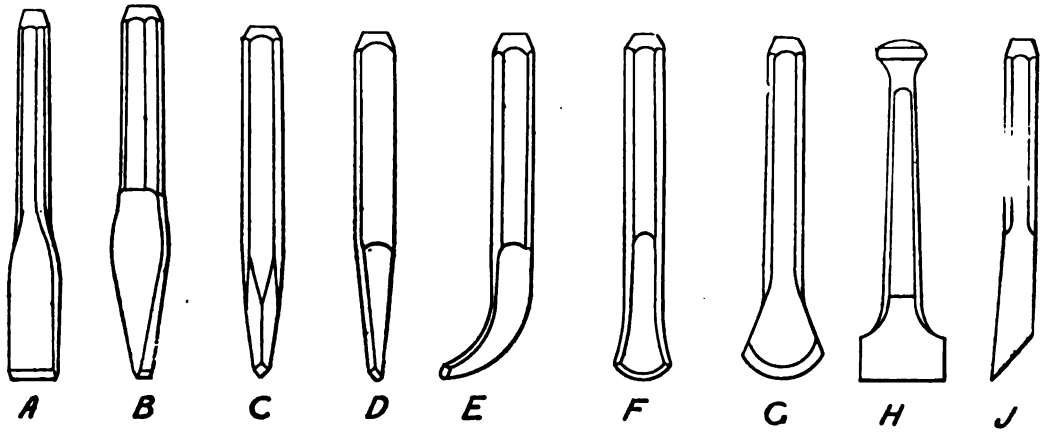


Fig. 188.—Chipping Chisels.

Chipping Hammer.—Either of the bench hammers used by the fitter, weighing about 1½ lb. each.

Chipping Strips or Chipping Pieces.—Narrow strips of metal cast above the area of a broader surface to form faces for exact fitting without the necessity for cutting over the entire area. They are a survival from the old days when such faces were cut by the chisel and hammer, instead of by planing, shaping, or milling. They are retained as planing strips because of economy in tooling. If they go all round the edge of the foot of a casting there is no economy if the tool is allowed to travel all across, so cutting wind during the greater part of the time. They should then be shaped with short strokes, or milled. Or parallel strips can

be set side by side, the objection to which lies in the broken open spaces at the ends.

Chisel.—For wood.—In all forms of cutting tools the chisel edge is always present, and does its work in the same way, no matter how the body of the tool varies in form. But the members of the group of cutting tools strictly termed chisels, are very much alike in general appearance, though there are a great many varieties. They have long narrow bodies with a wedge-shaped cutting end. The bevel of the wedge may be ground only on one face, leaving the opposite one parallel with the body; or on both faces, so that they converge from the body to the cutting edge. Wood-working chisels, which are the most numerous and important, are, with one or two exceptions, ground only on one face.

The angle to which these tools are ground is governed by the hardness of the material they are intended to cut. The softer the material, the more acute is the angle of the cutting edge. There is therefore a great difference between the angles of wood-working chisels and those intended for metal, and the same rule applies to all other cutting tools employed on these diverse materials. Where great strength is required, angles cannot be made very acute, or they would break under the pressure of their work, or become dull at the first stroke. When a tool angle is just sufficiently obtuse to give enough permanent strength to the keen edge, the tool is ground correctly. In wood-working chisels this angle ranges from about 15° to 30°. In these the cutting edge has to be made keener than it is possible to make it merely by grinding to the correct angle on a grindstone; and as the hone or oilstone which imparts the finer edge removes the steel very slowly, it is necessary in sharpening to tilt the chisel to a slightly more obtuse angle than the ground one. When freshly ground and sharpened, the ground angle goes right to the cutting edge, with no perceptible change of angle, and it is then that it cuts best. But after repeated sharpenings a distinct change of angle may be seen, and unless the chisel is tilted more and more on the oilstone it takes longer to sharpen it. The edge is stronger as it gets worn back in this way, but in time regrinding is necessary.

A chisel performs its work by a wedge-like action which removes a shaving or chip from a large body of material. Its keen edge is forced into the surface of the material, which divides on either side. If, as in splitting wood, the material on both sides is too thick to curl away, it gets forced apart by the body of the chisel, and splits in advance of the cutting edge, as in the axe, so that the action is no longer a cutting, but a wedging one. The ordinary work of the chisel, however, is to cut or sever the wood, by its edge, and when the thickness to be removed by this method is too great for one cut to effect, it is reduced gradually by removing successive shavings or chips.

A chisel may be used with either face to the body of the material. In paring a flat surface, or cutting mortises or edges square with the surface, the flat face of the chisel should be toward the surface or the line which is being cut by, because this face acts as a guide, and the direction of the cut will coincide with it. If the ground face is turned to the material, as is sometimes necessary, the chisel, instead of lying parallel with the surface, must be tilted until the cutting edge begins to penetrate. There is then no guide whatever except the control exercised by the hand, and long cuts of uniform depth cannot be made thus, because very slight variations cause the cutting edge either to go deeper and stick, or turn up to the surface and finish the shaving.

The chisel may be made to cut either by steady thrusts, straight forward, or diagonally; the latter when it can be employed makes easier and cleaner cutting; or by holding and guiding the chisel with one hand and driving it by blows of a mallet in the other. Malleting is generally only adopted when pushing by hand is too arduous or inadequate.

The three main varieties of wood-workers' chisels are the firmer, paring, and mortise. The difference between these is chiefly in length, and stoutness or strength.

The firmer, or short chisel, Fig. 189, A, occupies the medium position in this respect, and is the one most commonly employed for ordinary work, being used indiscriminately for paring by hand pressure alone, or by mallet blows.

The paring chisel, Fig. 189, B, is longer and thinner, and unsuitable for withstanding heavy

malleting. The advantage of its length and thinness is that it will reach over a greater distance, will wear longer, and is lighter, while quite strong enough for the hand paring it is intended for. Firmer and paring chisels are both made in widths ranging from $\frac{1}{16}$ in. to 2 in. Sometimes they have their backs bevelled or rounded, generally the former, to enable them to cut under vee edges, as in dovetailing. The coachmaker's or millwright's chisel is stouter, and is used for paring or malleting, Fig. 189, C.

Ordinary mortise chisels, E, range only from $\frac{1}{8}$ in. to $\frac{5}{8}$ in. in width, and chisel and handle are both made extremely stout to withstand heavy malleting, and also the prising action which is necessary in clearing out mortise slots. These chisels are used practically only for mortises, as for nearly all other work, thinner, or wider chisels are more convenient.

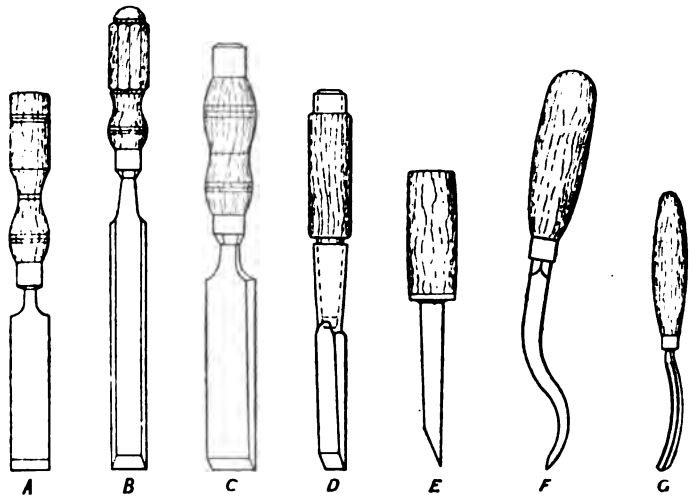


Fig. 189.—Wood-workers' Chisels.

Besides these three main types there are a number of others of a more or less specialised kind, used only in particular trades, or with but a limited range of usefulness. Besides the coachmaker's or millwright's chisels just noted, which combine the stoutness of the firmer with the length of the paring chisel, there is a class of heavy firmers almost equal to mortise chisels in stoutness. These are made in several forms, and are much used by carpenters. Some are known as socket chisels, Fig. 189, D, because they have a socket for the wood handle to fit into, instead of a tang to fit into the handle. Others are called framing or sash mortise chisels. There is also a curved variety known as lock mortise, or swan's neck, also dog leg chisels, F. These are suitable for use in recesses where a straight chisel would not cut. There are turning chisels, which differ from all the foregoing in being ground on both sides. Other less used varieties of chisel are drawer lock, which have their cutting ends bent at right angles for working in awkward places; sash pocket chisels, which are a very wide short variety; and button hole chisels, which are of similar proportions, but smaller. The carver's parting tool or vee chisel, G, has two chisel edges at right or acute angles. *See also* **Angles of Cutting Tools, Chipping Chisel, Cutting Tools, Hollow Chisel, Pneumatic Chisels, Setts, &c.**

Chisel Rod.—A section of drawn steel used for making chipping or cold chisels from. The section has two flat and two convex edges, or is of octagonal form. Chisels are, however, made of other sections, as circular, square, and hexagon.

Chloride of Iron, Fe_2Cl_6, crystallises in hexagonal, red brown scales or plates, which are very deliquescent and soluble in water, ether, or alcohol. It is prepared by passing chlorine over red-hot iron. By dissolving ferric oxide in HCl hydrated ferric chloride is obtained.

Chloride of Mercury.—Or Corrosive Sublimate, $HgCl_2$. This salt of mercury forms long and white crystals belonging to the rhombic system. It is soluble in 16 parts of cold water, but requires only 2 parts of hot water; melts at 288°, boils at 303°. It is prepared by heating mercuric sulphate, $HgSO_4$, and common salt, NaCl:—

$$HgSO_4 + 2NaCl = HgCl_2 + Na_2SO_4.$$

Chloride of mercury is used in surgery for its powerful antiseptic properties. It is highly poisonous, the white of raw eggs being the best antidote.

Chloride of Zinc, $ZnCl_2$.—Sometimes called Butter of Zinc. It is obtained by dissolving the metal, or its oxide, or carbonate in HCl and evaporating the solution. It is then white, translucent, very deliquescent, and melts at 100°. Its uses are as an antiseptic, a deodorant, a desiccant, and a caustic.

Chlorine, Cl, 35·45.—This element never occurs free in nature, but is found in combination with sodium as common salt, or with calcium, magnesium, and other metals. It may be obtained from salt, NaCl, by the action of sulphuric acid, H_2SO_4, and manganese dioxide, MnO_2:—

$$2NaCl + MnO_2 + 2H_2SO_4 = Cl_2 + Na_2SO_4 + MnSO_4 + 2H_2O.$$

Or by heating MnO_2 with hydrochloric acid:—

$$MnO_2 + 4HCl = MnCl_2 + 2H_2O + Cl_2.$$

This latter is the method adopted for its commercial production, the chloride of manganese being reconverted by treatment with lime into manganese dioxide (Weldon's Process).

Chlorine is a yellowish-green gas (Gr. *chloros*, pale green), with a powerful, irritating, and suffocating odour; sp. gr., 2·4, and hence it may be collected by downward displacement; liquefied at ordinary temperature under a pressure of six atmospheres, and then has sp. gr., 1·3; it is a very active element, combining directly or indirectly with most of the other elements.

Chlorine is remarkable for its great affinity for hydrogen, even decomposing water in the sunlight, liberating the oxygen and uniting with hydrogen. For this reason chlorine acts as a powerful indirect oxidiser, and hence as a bleaching agent, for in the presence of moisture it liberates oxygen, and this nascent oxygen acts destructively on vegetable (but not mineral) colouring matters. Bleaching powder is a compound formed by passing chlorine over dry and slaked lime.

Chock.—Signifies the casting which supports the bearing for the neck of a steel roll and its housings. It is adjustable for height to compensate for wear. It may be slung by bolts in a supporting bar. The term is also used to denote a mass of timber or metal which affords temporary or permanent support to an object, and is thus employed indiscriminately in all the shops.

Choke Damp.—Called also after damp, black damp, and foul damp, is the name given to the carbon dioxide produced by the explosion in mines, of fire damp or light carburetted hydrogen. Its presence in quantity frequently causes deaths after an explosion.

Chops.—A term applied to the jaws of a vice.

Chord Pitch.—*See* **Arc Pitch.**

Chord.—The chord of an arc is the straight line joining the extremities of the arc; in circles, ellipses, parabolas, and so on, a chord is the line which joins any two points in a curve. Occasionally problems in mensuration arise involving chords of circles. In Fig. 190 (1), BDC is an arc; BC is called the chord of the arc; BD and CD are chords of half the arc; and ED is the height of the arc.

To find the diameter of a circle when the height of an arc and the chord of half the arc are given:—Divide the square of the chord of half the arc by the height of the arc.

To find the diameter of the circle when the chord of an arc and height of arc are given:—Square half the chord, divide it by the height, and add the result to the height of arc.

To find the height of an arc when the chord of half the arc and the diameter of the circle are given:—Square the chord of half the arc, and divide by the diameter of the circle.

To find the chord of half the arc when the height of the arc and the diameter of the circle are given:—Take the square root of the product of the diameter of the circle and the height of the arc.

The chord of an angle of 60° is always the same length as the radius of the circle.

Chords—Scale of.—By means of the scale of chords any angle may be constructed or measured. Its construction is shown in Fig. 190 (2, 3, 4). The angle ABC (2) is a right angle, and its arc AC is divided, in this case, into 18 divisions of 5° each. If angles of less than 5° are to be constructed the arc should be divided into 90 parts of 1° each.

To construct any angle, say 80°, by means of the scale of chords, an arc is described with a radius equal to the length C, 60°, Fig. 190 (3). *This must always be done for any angle.* Then

with a radius equal to C, 80°—the number of degrees required, the arc is cut as at A. The angle ABC measures 80°. Angles greater than 90° may be constructed by marking off successively two or three arcs equal to the total number of degrees required. Thus for an angle of 115°, describe an arc, Fig. 190 (4), with radius equal to C, 60°, cut it with the same radius, and with the compasses in the latter point cut the arc again with C, 55°. Then C, 60° + C, 55° = 115°.

To measure any angle with the scale of chords, describe the arc AC, as in Fig. 190 (3), with a radius equal to C, 60°. Then measure AC, and by

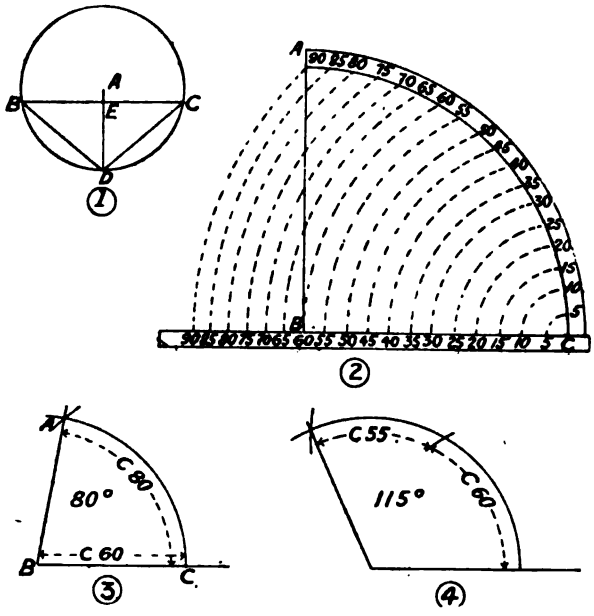


Fig. 190.—Chord, and Scale of Chords.

placing the compass legs on the scale the number of degrees is immediately seen. In some cases it may be necessary to lengthen the sides containing the angle so that the radius C, 60°, shall cut them. This of course does not increase the size of the contained angle.

Chrome Iron.—Chromium does not act upon iron in the same way that it does upon steel, because the influence of carbon is necessary to produce that effect. In cast iron, therefore, where carbon is present only in small quantities, the addition of as much as 2 per cent. of chromium does not affect the crystallisation. So long as carbon is about 0·30 per cent. and under, the effect of chromium upon the crystallisation of iron is small, but when present in higher percentage its action is different. The carbon then enables the chromium to act more energetically, and to combine more readily with the iron.

Chrome Steel.—Denotes various grades of steel into the composition of which chromium enters in varying proportions, and confers hardening. Hence its value lies in the manufacture of armour plate, projectiles, railway tyres and springs. The proportions of chromium added, range from about 1 to 2·75 per cent., the higher quantities being suitable for armour-piercing projectiles. But the presence of carbon in the combined form is also necessary, up to from 0·9 to 1·0 per cent. Chromium up to about 1 per cent. does not affect steel. It is added in the form of ferro-chromium, which is prepared in the blast furnace up to 70 per cent. of chromium. Rich ferro-chromium is melted with difficulty, and when poured it cools much more quickly than carbon steel does. Mr Hadfield stated that he had seen pieces of rich ferro-chromium come out of the crucibles unmelted, though subjected to the intense heat of a Sheffield crucible furnace. Chromium does not confer soundness on steel, but the presence of carbon affects results.

Neither in iron or steel can chromium yield much advantage if the carbon is low, hence the term chromium-carbon steel. But with carbon in considerable proportions, the result of adding chromium is to increase tensile strength and elastic limit without diminishing elongation, in this respect having the opposite results to those obtained in the carbon steels. In some specimens, Mr Hadfield obtained a tensile strength of 104 tons per square inch with 3 per cent. ductility. Mr Hadfield well remarked that "the exact *rôle* played by a third element in an alloy or mixture such as steel, is a complex one. It is one of those metallurgical puzzles in which the help of the Wise Men of the East would be very useful."

Chromium steel hardens readily, besides being hard in itself, hence its value for projectiles. But with increase in hardness, difficulties occur

in treatment which are not present in the softer varieties. The grain is exceedingly fine grained, but if overheated it is more liable even than carbon steel to develop a coarse and weak crystallisation.

Chromium, Cr, 52·1.—Occurs chiefly in chrome ironstone, $FeOCr_2O_3$, and lead chromate, $PbCrO_4$. It is prepared in three or four ways, but most commonly by reducing chromic oxide, Cr_2O_3.

Chromium is a hard, grey, and very infusible metal, requiring even a higher temperature than platinum for fusion. It is used for hardening steel and the iron of projectiles (*see* **Chrome Steel**) and is also valuable for the variety of its coloured compounds. The amorphous oxide is a beautiful green powder, which gives a deep green colour to glass, porcelain, wall papers, &c. Bichromate of potassium, $K_2Cr_4O_7$, is used in calico printing, and also in photography, owing to its property of rendering gelatine which it has impregnated insoluble on exposure to light. The various chrome yellows, pigments, and dyes, consist of lead chromate. Chromium salts are detected by yielding a yellow mass when fused with carbonate of soda and nitre, and by giving a green bead with borax.

Chronograph (Gr. *chronos*, time; *grapho*, to write).—Is a term applied to devices not only for *measuring* time like the **Chronoscope**, but also for automatically *recording* it. The essential parts of the numerous types used are a revolving cylinder round which paper is wrapped, and a marker which moves in a direction parallel with the cylinder's axis. In some instruments the paper is ruled with parallel lines so that if a large cylinder makes one revolution per minute, very minute fractions of time can be recorded. In others the marker itself makes an impression on the paper every second, being electrically connected with a clock. By depressing a key the current is established at any intermediate portion of a second, and so an observer is able to mark even to the $\frac{1}{100}$th part of a second the instant an event occurs, or the interval between two occurrences. Its value is seen in observing the transit of a star, the velocity of projectiles, the swing of a pendulum, and the speed of animals and machines.

Bashforth's Chronograph was designed to measure the flight of projectiles by making the bullet in its flight pierce a series of screens. As each screen was pierced the current was broken, and the marker connected with the armature of an electro-magnet made a sudden jerk, and consequent record on the cylinder. Immediately the current was automatically established, to be again broken as the projectile pierced the next screen. An examination of the cylinder then showed what velocity the projectile possessed at different periods in its flight.

Chronoscope (Gr. *chronos*, time; *scopeo*, to see).—Is a name which has been given to several instruments for measuring very brief intervals of time. Sir Charles Wheatstone invented a chronoscope to measure the duration of an electric spark. A rapidly revolving mirror reflected the light so as to whirl this reflection through an arc of a circle, the length of the arc measuring the duration of the light. As a matter of fact the electric spark produces no arc, thus proving that it is far from having the duration which the persistence of its impression on the eye would lead one to suppose. Foucault and Fizeau pursued their historic investigations as to the velocity of light by means of revolving chronoscopes. *See* **Chronograph**.

Captain Noble's Chronoscope is designed for accurately recording the velocity acquired by a shot in its passage through a gun specially designed for testing purposes. The pressure of the gas generated at different positions is also measured by another device. The principle in brief is this:—

Holes are bored in the sides of the gun at gradually increasing distances from breech to muzzle. Plugs are screwed into these, each having a wire passed through it very close to the bore, but leaving sufficient room for a pivoted knife, which being pushed up against the plug by the passage of the shot severs the wires in succession.

These several wires are connected to the primary wires of an induction coil with which the secondary wires communicate. Hence when the wires in the plugs are cut, the primary currents are broken, and sparks pass in the secondary. These are made to register the successive velocities of travel by an ingenious

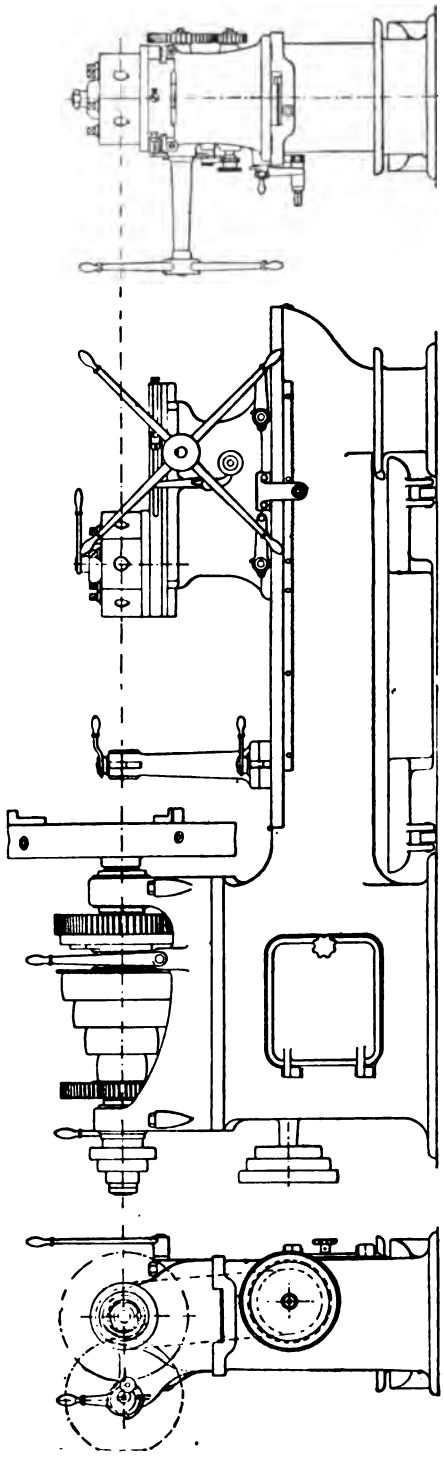


Fig. 191.—Chucking Lathe by De Fries & Co., Düsseldorf.

mechanism of revolving discs. These discs are rotated by a horizontal shaft at a peripheral speed of about 1,100 inches per second by toothed gears, and regulated by a descending weight. A stop clock records the rate of revolution of one of the gear wheel shafts. A vernier at one end of the shaft reads on a graduated circle fixed on the shaft. Opposite the edge of each disc, and close to it is a discharger which receives one of the secondary wires, while the other wire is in contact with the disc. The edges of the discs are coated with lamp-black. When a wire is cut, sparks pass from the discharger to which it is connected, and burn off the lamp-black from the part of the edge passing at the instant, leaving a spot.

When the shot has passed the chronoscope is stopped, and the spot in each disc is brought in succession opposite an index, and the spaces travelled by the disc between each successive spot are read off on the graduated circle on the end of the shaft by the aid of the vernier, within $\frac{1}{100000}$th of a second of time. In this way the time occupied by a shot in travelling between successive plug holes is ascertained.

The pressure of the gases is measured against plugs of pure copper inserted in other holes, the lateral extension of which under different pressures has been ascertained by previous experiments.

Chuck, Chucking.—Any appliance employed either for gripping work, or tools may be termed a chuck. The name is, however, more properly restricted to lathe and drilling machine chucks (references to the various types of which will be found under different heads). Although some classes of chucks are used for varying purposes, when a considerable run of repetition work is handled, special chucks are preferably brought into use, so that we find Drill Chucks, for example, constituting a large group by themselves, while special shapes of jaws provide in other cases means of holding irregular forms. The wire chucks of split type are another instance of a special function, that of gripping rods of plain form, in automatic screw machines and capstan lathes. One great distinction between chucks is that of self-centring or independent; the first automatic-

ally centre regular pieces, and save tentative setting, while the latter allow of adjustment to suit rough pieces of irregular contour, or those that have to be set eccentrically. Chucks are either separate and detachable from their machines, or are built into them, and always remain, such as in Boring Mills, and some types of lathes. The grip of jaws may be frequently sufficient to hold the work; in other cases supplementary aid is requisitioned, by bolts and clamps.

Chucking Lathe.—Also called Boring Lathe. A special type which is employed for boring and facing work held in a chuck, as distinct from that between centres, or on a mandrel; either preparatory to subsequent operations, or as a complete finishing process. It is cheaper and better to treat pieces having bores, first, on this class of lathe; and then let the turner carry on the other work, as turning on a mandrel, screwing, &c., in a separate lathe. The method lends itself to accurate boring also, because a large number of pieces render the use of chucking drills and reamers possible, instead of having to bore with a side tool, from the slide rest.

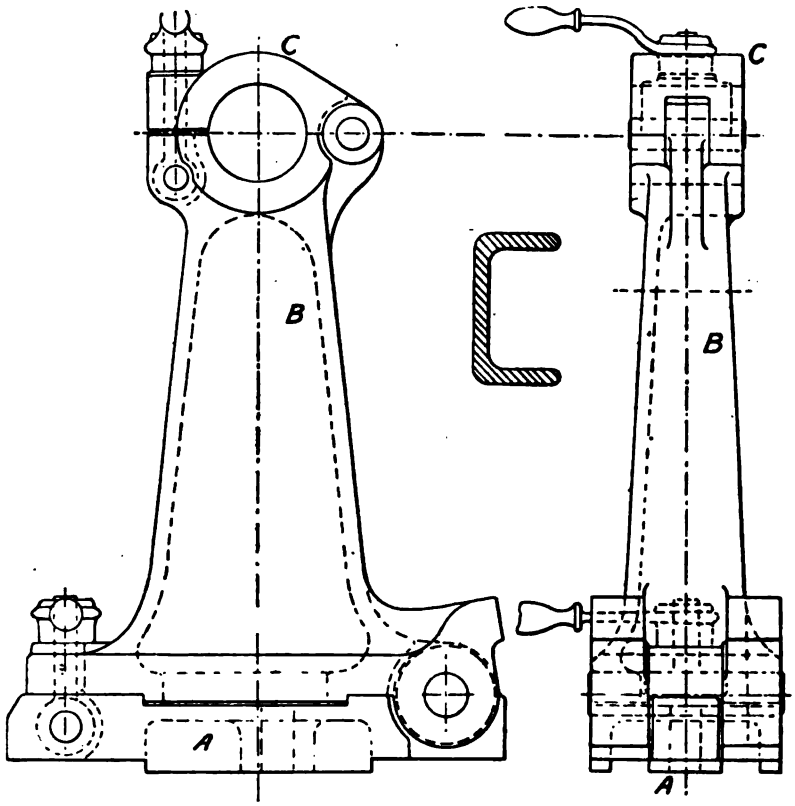


Fig. 192.—Boring Rest for Chucking Lathe.

A typical example is seen in Fig. 191, the principal features of which are the turret, mounted on a high base piece, and the boring rest (seen to the right of the chuck). Both hand and self-acting feeds are given to the turret, and stops are fitted. The six flat faces of the turret permit of bolting heavy boring and facing tools thereto. Friction backgear is fitted to the headstock, so that changes may be readily effected, for example in boring a small hole, and facing a large diameter. The boring or steady rest, which is the most special feature of the lathe, is seen in detail, Fig. 192, from which it will be seen that a base plate A, bolted to the bed, has the pillar B hinged to it, and fastened at the front with a handle and eye-bolt, permitting of rapid loosening and throwing back of the steady out of the way. The cap C is also hinged similarly, so that it may lay the bearing open for the reception of tool shanks. Without the use of this steady, it would be difficult or impossible to start a true bore from a cored hole, using the ordinary drills, because these are easily coerced by a rough bore, and a hole neither circular nor true concentrically would result.

Chucking Plates.—A group of special fixtures for lathes in which certain dimensions are embodied without having to fix them for every job. In crank-chucking plates the throw

of the crank is embodied, in those for the plugs of sluice cocks the taper of the plugs, in those for eccentrics the throw.

Chucking Tools.—These are a particular type, developed in recent years, for the class of boring and reaming performed on turret and chucking lathes, their special feature being that of length, so that deep holes may be operated on. The shanks are gripped in the holes of the turrets, and for fine finishing operations, a floating holder is employed. Various forms of drills, both two, three, and four-lipped are used, and reamers also with three or more lips, particulars of the shapes of which will be found under **Reamers** and **Twist-Drills.**

Chute.—A trough which conveys the water to a turbine. Also employed in connection with certain machine operations, for leading materials or partly finished pieces to the gripping mechanisms (in Magazine Feeds), and for removing them after tooling.

Cinder Bed.—A layer of hard clinkers from cupola furnaces, or of hard coke laid down to about a foot in thickness, at a depth of a foot or more below the bottom of a bedded-in foundry mould. Layers of hay alternate with the clinker or coke to render the mass more porous. It receives the vents from the lower portions of the mould. A cinder bed will last from six to twelve months in regular use before it becomes choked up.

Cinder Pig.—An inferior grade obtained by treating in the blast furnace the rich slags or cinders of the puddling furnaces with a proportion of ores. The ferrous silicates of the tap cinder yield a good proportion of iron. The objection to its use is that it contains phosphorus from the puddling process, which enters into the composition of the cinder pig. It is also charged with sulphur in excess, and therefore tends to whiteness.

Cinnabar is the native sulphide of mercury, HgS, and from it the greater part of the mercury of commerce is obtained. The famous mines of Almaden in Spain have supplied the world for over 2,000 years; there are other mines at Idria in Austria, in Bavaria, China, Japan, California, and at Steamboat Springs in Nevada. It occurs either in red, crystalline (hexagonal) masses, or as a dark, amorphous powder. Sp. gr., 8·2. Vermilion is obtained from cinnabar by grinding the purer portions, or by triturating mercury (100 parts), and sulphur (18 parts), and subliming the black amorphous sulphide, out of contact with air. This is done by dry or wet processes.

Circle.—A circle is an area bounded by one line (the circumference or periphery), every point of which is equally distant from a point within it (the centre).

The ratio between the diameter and the circumference of any circle, whether the dimensions be inches or miles, never varies. Roughly this ratio, often represented by the Greek letter pi, π, is $3\frac{1}{7}$, and if the diameter be 1 inch or 1 yard, then the circumference will be $3\frac{1}{7}$ inches, or $3\frac{1}{7}$ yards respectively. Thus the rule for finding the length of the circumference is: multiply the diameter by $3\frac{1}{7}$. This makes the circumference too long by 1 inch in 2,485 inches. It is of course near enough for all practical purposes, but if greater exactness is required, multiply by 3·1416, which gives an excess of circumference of only ·148 inch in a mile. (The calculation of this ratio has been worked out to over 600 decimal places.) The diameter is found by the reverse operation—dividing the circumference by $3\frac{1}{7}$ or 3·1416, which is equivalent to multiplying by $\frac{7}{22}$ or ·31831. The radius is, of course, always half the diameter, and can be found when area only is given, by the rule on p. 185, Vol. I.; *i.e.*, area = radius^2 $\times 3\frac{1}{7}$, or area = diameter^2 $\times$ ·7854. Therefore the radius is found by dividing the area by $3\frac{1}{7}$, and extracting the square root of the quotient; or the diameter by dividing the area by ·7854, and extracting the square root of the quotient. To avoid dividing we may multiply, as shown in the summary of rules on next page, by the reciprocals of $3\frac{1}{7}$ and ·7854, which are ·3183 and 1·2732 respectively. Rules for finding the areas of segments and sectors, and of circular rings, are given under **Areas**, and the rule for finding the length of an **Arc** under that term. *See also* **Chord.**

The following table gives a useful summary of the mensuration of the circle. C = circumference; D = diameter; A = area; R = radius.

MENSURATION OF THE CIRCLE.

$C = D \times 3\frac{1}{7}$	$D = C \div 3\frac{1}{7}$	$A = D^2 \times \cdot 7854$
$C = D \times 3 \cdot 1416$	$D = C \div 3 \cdot 1416$	$A = \frac{1}{4}C \times \frac{1}{4}D$
$C = \sqrt{A \times 12 \cdot 566}$	$D = \sqrt{A \times 1 \cdot 2732}$	$A = R^2 \times 3\frac{1}{7}$
$R = \sqrt{A \times \cdot 3183}$		$A = C^2 \times \cdot 07958$

The angle at the centre of a circle is double that of the angle at the circumference on the same base, that is, on the same arc. In Fig. 193 (1) the angle AED is double ABD or ACD, each standing on the same arc AD. *The angle in a semicircle is a right angle.* In Fig. 193 (2) ACB and ADB are each right angles. But in a segment greater than a semicircle the angle is less than a right angle, and in a segment less than a semicircle the angle is greater than a right angle. In

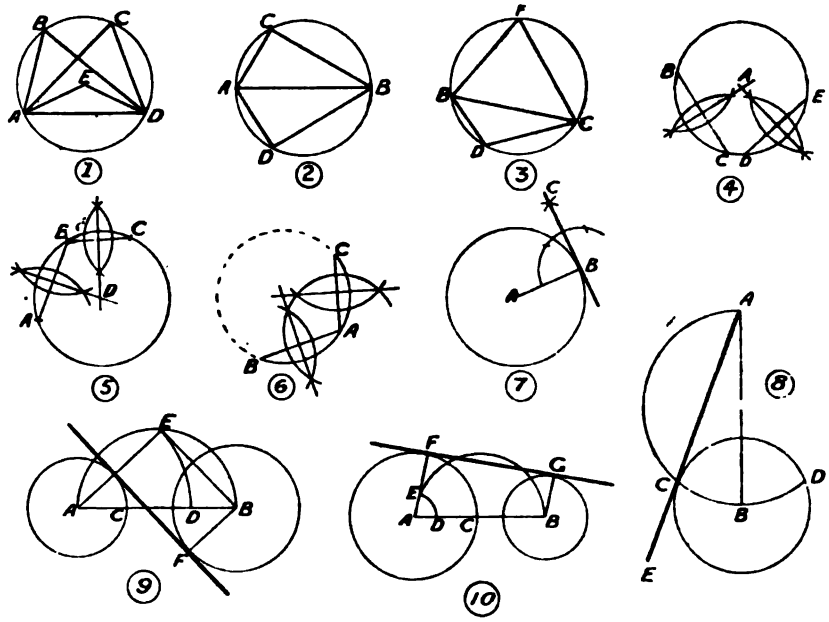


Fig. 193.—Properties of the Circle.

The following three useful rules deal with the relations between squares and circles:—

1. To find the side of a square equal in area to a given circle; multiply diameter by ·8862.

2. To find the diameter of a circle equal in area to a given square; multiply the side of the square by 1·1283.

3. To find the side of the greatest square in a given circle; multiply the diameter by ·7071.

The third book of Euclid gives a number of valuable and useful geometrical truths and properties connected with circles, of which the following are the more important. *The angles in the same segment of a circle are equal to one another.* In Fig. 193 (1) the angles ABD, ACD, in the segment ABCD are equal to one another. Fig. 193 (3) the angle BDC in the lesser segment is greater than a right angle, but BFC in the greater segment is less than a right angle.

Geometrical problems connected with the circle:—

1. To find the centre of a circle, Fig. 193 (4). Draw any two chords, BC and DE, and bisect them. A, where the bisecting lines intersect, is the centre of the circle.

2. To draw a circle through any three points, not in a straight line, Fig. 193 (5). If A, B, C, are the three given points, join AB and BC, and bisect these two lines. The point D of intersection of the bisecting lines is the centre of the circle, which may then be described with DA as radius.

3. To complete a circle when only a portion of its circumference (an arc) is given, Fig. 193 (6). Take any point A in the given arc BC, and join AB, AC. Bisect these chords, and the point of intersection of the bisecting lines is the centre of the circle.

4. To draw a tangent to a circle from a given point in the circumference, Fig. 193 (7). Join the given point B with the centre A, and at B draw BC perpendicular to BA. BC is then a geometrical tangent to the circle.

5. To draw a tangent to a circle from a given point *outside* the circle, Fig. 193 (8). Let A be the point. Join AB, bisect it, and so describe arc ACD. From A, through C, draw ACE, which is then a tangent to the circle. A second tangent might be drawn from A through D.

6. To draw a tangent to two unequal circles. The tangent may be "interior," that is, may cross the space between the two circles, as in Fig. 193 (9), or "exterior," as in Fig. 193 (10). Taking first the case of the interior tangent. Join AB, bisect it, and so describe the semicircle AEB; make CD equal to the radius of the larger circle. With centre A, and radius AD, describe the arc DE. Join EB, and draw AE, FB perpendicular to EB. A line drawn through the points where these perpendiculars cut the circles will be the required tangent.

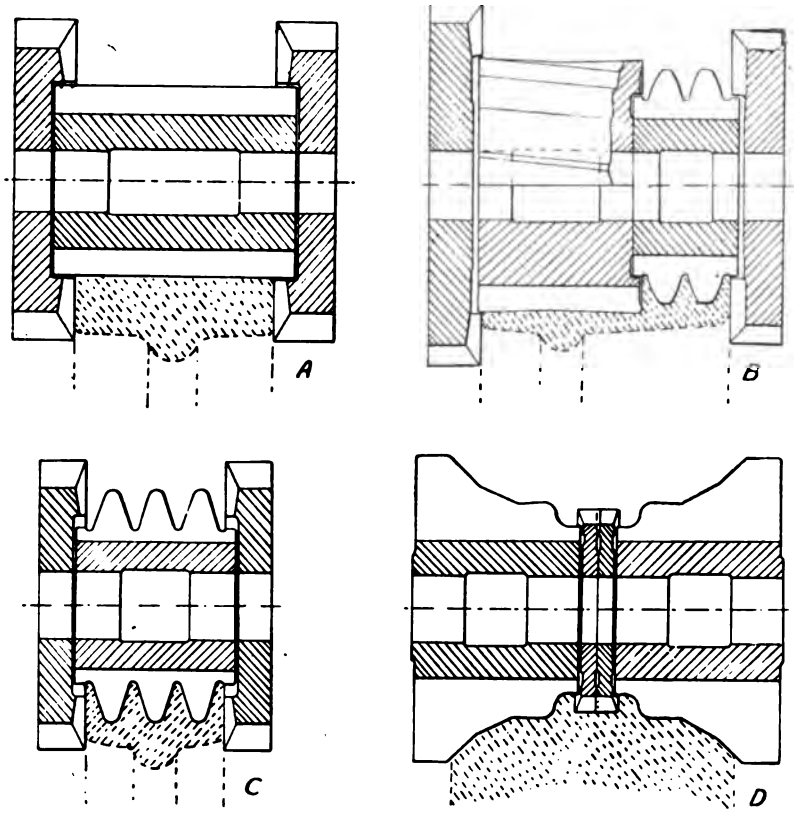


Fig. 194.—Circular Milling.

7. To draw an exterior tangent, Fig. 193 (10). Join AB, bisect it, and describe semicircle as before. Make CD equal to radius of smaller circle, and with centre A, and radius AD, describe DE cutting the semicircle. Through E draw AF, and draw BG parallel to AF. FG is the required tangent.

Circuit Breaker.—*See* **Switch.**

Circular Attachment or **Circular Motion.**—*See* **Shaping Machine.**

Circular Inch.—A circle of 1 inch diameter = ·7854 of a square inch. It is usual to reckon pressures, &c., in square inches.

Circular Milling.—A development which has sprung up in recent years, for milling the peripheries or faces of work while revolving, instead of turning. The results achieved are satisfactory, both from the point of view of accuracy, and especially rapidity, since a deeper cut may be taken than is possible on the lathe, notably in light flimsy wheels, which chatter and spring under a heavy turning feed. One of the commonest applications is for preparing the rims of gear wheels for cutting the teeth; belt and rope wheels are also commonly done. Fig. 194 shows four different types of cutters used, as examples of the style. A is for plain

peripheries and edges of rims, three cutters being mounted together on a mandrel; B tools a combined belt and rope pulley; C a rope pulley; D is an example of a profiled shape, involving the use of four cutters. Adjustment for wear sideways is easily made by the employment of thick, or thin washers between the cutters; it will be noticed that the end mills in each case stand off a little from the others, to allow of this subsequent closing in. All the cutters are preferably of the backed-off or relieved type, giving the greatest strength, and permanence of profile notwithstanding repeated sharpenings.

The machine on which these cutters are employed is shown in Fig. 195, Plate XV. A headstock drives the cutters at various rates, and the work is held on a mandrel, rotated by the head seen to the right, an outboard support carrying the tail end of the mandrel and steadying it. The outer end of the cutter arbor is also steadied similarly. The work is revolved by a worm wheel inside the casing, and this can be thrown out of gear, and hand rotation effected, for purposes of adjustment. The direction of rotation of cutter and work is important; they must not run so that the peripheries travel towards each other, but opposite, so that as the cutter teeth are moving downwards, the work is travelling around in an upward direction.

Fig. 196, Plate XV., shows how circular milling is done with the help of the circular table, rotated on the plain table of the milling machine, either by hand, or automatically. In this example a vertical spindle head is fitted to a pillar-and-knee type of machine. The piece being tooled is a quadrant plate, finished on two faces, and outer edge by gang cutters.

Circular Pitch.—The pitch of wheel teeth measured round an arc of the pitch circle, as distinguished from **Diametral Pitch**, which is a function of the pitch diameter.

Circular Plane.—A plane which has its sole in the form of a sweep longitudinally. Generally such planes are of metal, with a thin flexible steel sole which can be adjusted to any curve, either convex or concave. When made of wood to a fixed sweep they are generally of the smoothing plane type, and are cut to a sufficiently small convex sweep to be suitable for planing almost any concave surface. It is not very often that such planes are required. They are used merely for smoothing and removing tool marks from surfaces that have already been cut to the sweep by tools working in the transverse direction. Very often a spokeshave is a satisfactory substitute for a circular plane, but when curved surfaces are large, and accuracy is important, a circular plane is always better.

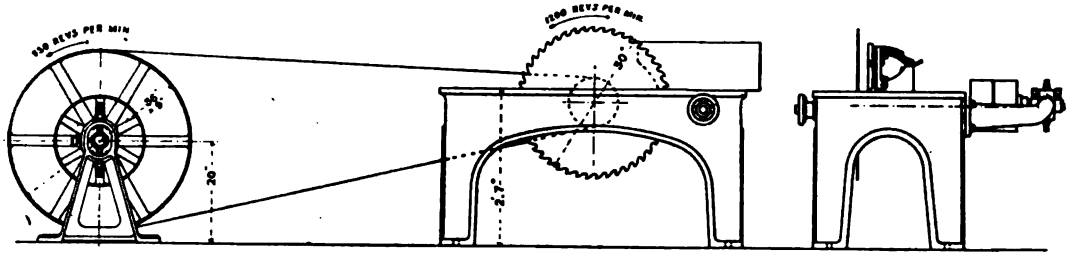


Fig. 197.—Circular Saw. (A. Ransome & Co., Ltd.)

Circular Saw Bench.—The varieties of this machine are numerous, ranging from the large types for cutting up logs to the small benches used in shops for finishing operations of different kinds. The essential portions of a typical bench are seen in Figs. 197, 198, giving side and end elevations, driving pulley on the floor, canting fence, and a sectional view of the spindle, with its bearings and fast and loose pulleys. The changes rung on a simple design of this character are numerous, a few of which are seen in the photos, Figs. 199-204, Plate XVI. The principal features relate to the methods of feeding the timber, and to the angling of tables. Fig. 199 shows a "rope-feed" machine, in which a drum (seen in front) winds a rope which draws the timber along at a rate determined by the speed of the drum, a cone pulley allowing of

variations. The two carriages seen on rails at each end support the balks at a uniform height with the table. Other methods of feeding large pieces comprise the rack bench, or table which travels bodily with the timber, and the endless chain, passing under the balk, and driving same along by a dog inserted between the links. The roller-feed device, seen in Fig. 200, Plate XVI., has the advantage of continuous feeding, so that pieces can be supplied as fast as the saw gets through them. The movement is effected by the two corrugated rollers seen to the immediate right of the saw, these being mounted on a radial arm to accommodate various thicknesses of stuff. The smooth rollers carried in the vertical frame at the back support the timber truly. The radial arm is pulled over against the timber by the counterweight seen, imparting sufficient "bite" into the wood. A machine having a different mode of driving the feed-rollers—by concealed gearing and shafts within the arm, is seen in Fig. 201, Plate XVI. Another variety of saw-bench, with rising and falling table, is seen in Fig. 202, the vertical adjustment being employed when tonguing, grooving, rebating, &c. Bevel gears driving screws provide the means of alteration in height, the gears being revolved by the handwheel seen on the right.

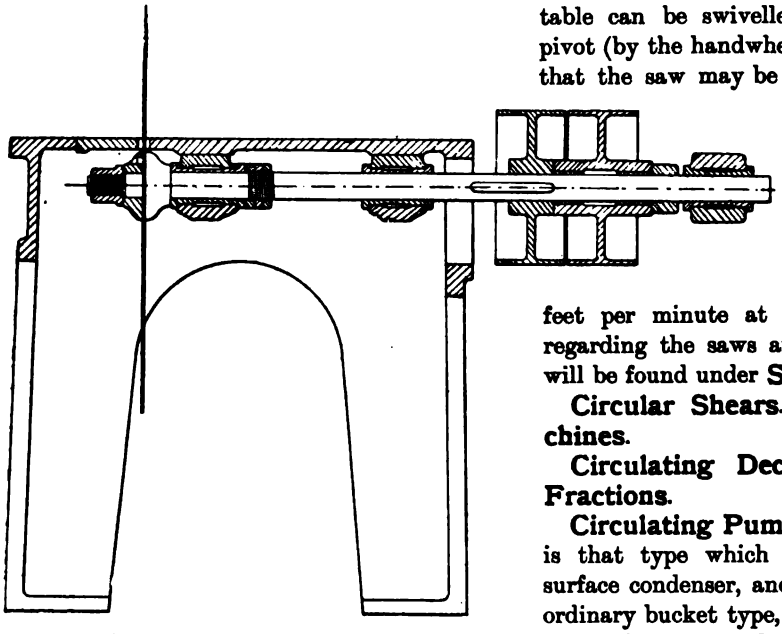


Fig. 198.—Circular Saw. (A. Ransome & Co., Ltd.)

A large class of benches have provision for angling the table, as in Fig. 203, for cutting bevels, the tilting motion being produced by a quadrant rack, and pinion, worked by the large handwheel.

For certain purposes portable benches are useful, as in shipyards, on large contracts, &c., so that the saw may be taken about to the work, as required. Fig. 204 illustrates a saw bench running on rails, and driven by an electric motor coupled direct to the spindle. A valuable feature of the design is that the table can be swivelled around on its central pivot (by the handwheel, and worm gearing), so that the saw may be presented as convenient to the work, saving awkward handling about of the latter in confined situations.

The speed of a circular saw ranges between 9,000 and 10,000 feet per minute at the teeth. Information regarding the saws and their sharpening, &c., will be found under **Saws.**

Circular Shears. — *See* **Shearing Machines.**

Circulating Decimals. — *See* **Decimal Fractions.**

Circulating Pump.—The circulating pump is that type which drives water through a surface condenser, and it may be either of the ordinary bucket type, horizontally or vertically disposed, or it may be of centrifugal type.

In marine engines of moderate power the circulating pump is often driven from the crosshead of the main engine by a lever and links exactly as the air pump is driven. In larger engines the pump is separately driven.

For stationary work, when of centrifugal type, the pump is often driven by an electric motor. When of bucket type it is usually driven by its own steam cylinder. Where water is scarce, the duty of forcing the water through the condenser to the top of the water-cooling tower is thrown upon the circulating pump. With cold water of 50° Fahr. the capacity of



Fig. 199.—Circular Saw with Rope Feed.
(Thos. Robinson & Son, Ltd.)

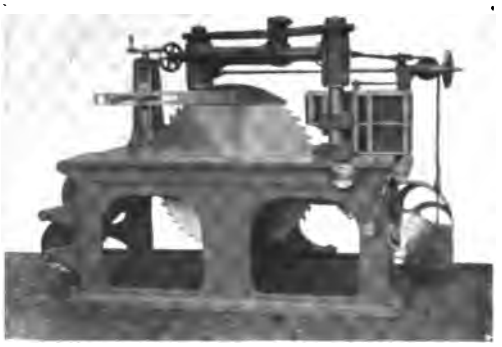


Fig. 200.—Circular Saw with Roller Feed.
(Thos. Robinson & Son, Ltd.)



Fig. 201.—Circular Saw with Roller Feed.
(Kirchner & Co.)



Fig. 202.—Saw with Rising Table and Canting Fence.



Fig. 203.—Saw with Tilting Table.
(Thos. Robinson & Son, Ltd.)



Fig. 204.—Electrically Driven Portable Type of Saw Bench. (Kirchner & Co.)

To face page 238.

the pump must be such as to throw twenty to twenty-five times as much water as the engines consume in weight of feed water to the boilers. With hotter water the proportion must be more liberal according as the temperature approaches the limit of 100° Fahr. Thus at 75° Fahr. the circulating water must be fifty times the weight of feed water.

The pump illustrated, Fig. 205, is by Hick, Hargreaves, & Co., Ltd., and consists of a double vertical chamber with the hollow shell plunger, working between in a bored cylinder, and drawing in its supply by the valves on the right, and discharging by similar valves on the left side of the chamber. Note the slope of the pump top for facilitating the free escape of air.

Circulation.—The circulation of water in steam boilers is as important as the strength of the boilers themselves. If it is bad, overheating, incrustation, and loss of efficiency will result. The circulation is very different in different parts of a boiler. In a horizontal one, the greatest ebullition goes on over the furnace; expanding, and raising the level of the water there, and sending it towards the back of the boiler, whence in time colder water flows towards the front. The introduction of Galloway tubes increases the circulation by setting up a relative movement between the highly heated water in the tubes and the cooler water around the combustion flues. The water in the tubes nearest the bridge will moreover have a more active circulation than the water in those farther away. As showing the effect of violent ebullition in keeping boilers free from incrustation, it may be noted that incrustation is thicker at the back portions of a boiler, where the ebullition is least, than towards the front where it is greatest.

In the Lancashire boiler the circulation is not active until after the water has been brought to the boiling point. Steam may be making rapidly while the bottom of the front plate feels barely warm. In Mr Fletcher's report on the experiments on "Red-hot Furnace Crowns," in one case, the difference in temperature between the top and bottom of the water when boiling point was reached was 140° Fahr., and this was a Lancashire boiler with four cross water tubes! In three Galloway boilers the differences in temperature at top and bottom were respectively 134°, 141°, and 142° Fahr.! The reason is that at the beginning, practically the whole of the heat is received by the furnace crown; and the heat from the flues underneath, and at the sides of the shell, cannot raise the temperature

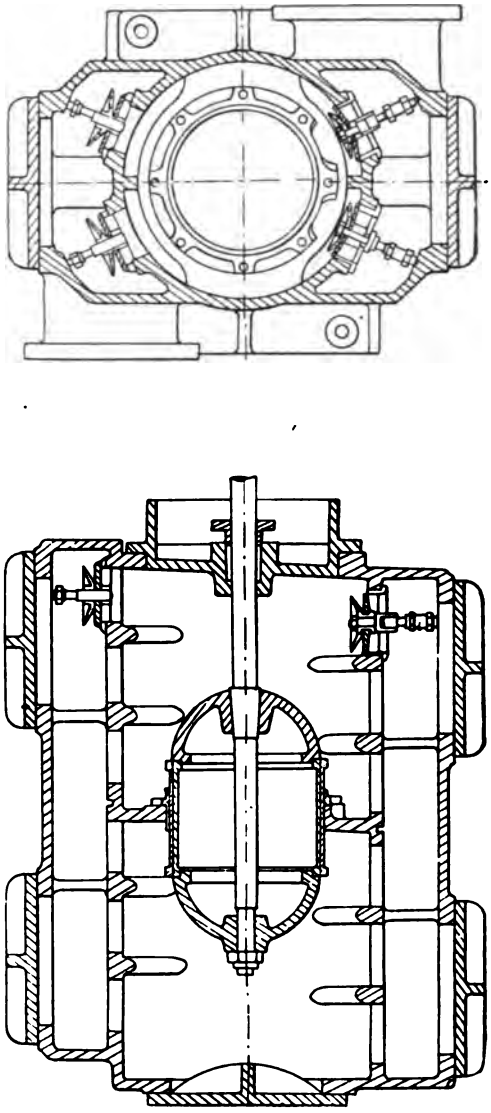


Fig. 205.—Circulating Pump.

sufficiently to quicken circulation. The circulation first passes from over the furnace end of the flues to the back, and from over the top of the flues along their entire length to the sides. The cooler water at the bottom and sides being

heated, rises and circulates in time, fresh supplies coming into the boiler as evaporation proceeds.

Circulation to be natural and efficient must be regular and even, not spasmodic. There is no doubt that many cases of overheating and of collapse in vertical boilers have occurred in consequence of impeded circulation. When a fire-box is unduly high, and the water space narrow, and little coning given to the fire-box, then the water is rapidly heated, and the steam is generated with so great force as to drive out a quantity of the water, and prevent cooler water coming down to cover the plates. If the water level fluctuates very rapidly in the gauge-glass impeded circulation may be suspected.

The circulation in water-tube boilers will be found treated under **Accelerated Circulation,** and other headings relating to the principal types of those boilers.

Circumference.—*See* **Circle.**

Civil Engineering.—This branch of engineering is best described in the words of the Charter of the Institution as "being the art of directing the great sources of power in nature for the use and convenience of man, as the means of production, and of traffic in states; both for external and internal trade as applied in the construction of roads, bridges, aqueducts, canals, river navigation, and docks; for internal intercourse and exchange, and in the construction of ports, harbours, moles, breakwaters, and lighthouses, and in the art of navigation by artificial power for the purposes of commerce, and in the construction and adaptation of machinery, and in the drainage of cities and towns."

This is a large extent of ground to cover, for it includes very much that is also mechanical engineering, as work in steel and iron, utilised in bridges, dock machinery, in lighthouses, in water works and sewage, in constructional and steel work generally, in cranes, and transport. It includes also a knowledge of many branches of science, mathematics, mechanics, heat, sound, light, electricity, chemistry, geology, metallurgy, steam. The civil engineer should know much of workshop practice and processes. In short the wider his acquaintance with mechanical engineering the better qualified will he be as a civil engineer. Many do not combine the two; but work in iron and steel, and power agencies in general, enter so largely now into civil engineering practice that the need of such comprehensive knowledge is felt more now than heretofore.

Civil engineering is entered by pupilage to a firm of engineers in practice, for which a heavy premium has to be paid, its amount increasing generally with the status of the firm. The work is chiefly laid in the office routine, in drawings and calculations, in details of the designs prepared by the firm. It may also include intervals of practical work in charge of men out of doors. Generally, however, this is reserved for junior assistants, ex-pupils. Some civil engineers do little or no outside work, being consultants only, or chiefly. The work of others lies mostly in the design and execution of great public works, and these offer the best opportunities to the pupil. For it must not be forgotten that office routine not supplemented by practice can never qualify a man for the carrying out of great public works, any more than an officer can be made without experience in campaigning. Therefore the aim of a pupil should be to get out on works as early as possible, before he has had time to become set in office routine. Out-door work is preferable from every point of view, notwithstanding that it is of an exacting character. But it hardens and broadens, giving one that resourcefulness and grip of things which can only be gathered in the school of experience.

Much study is essential to the making of a civil engineer. Study in youth as a grounding, and study maintained all through life. Reading to learn what others are doing must be persistently pursued.

The technical training of the civil engineer cannot be laid on too broad a basis. The question is how to gather it. A good education in a university is invaluable, but the great technical schools equipped with laboratories teach what the universities cannot do so well. The student must attend these, either before entering the office, or in alternation with the office work. It cannot be deferred till after pupilage, so that double work is the best solution of the difficulty.

We have concluded that it would be more advantageous to bind two volumes of this Encyclopædia in one volume. That is, volumes One and Two, Three and Four, Five and Six, Seven and Eight, and Nine and Ten, are each bound together; thus publishing the work in five bound volumes, instead of ten.

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HENLEY'S ENCYCLOPÆDIA

OF

PRACTICAL ENGINEERING

AND ALLIED TRADES

A PRACTICAL AND INDISPENSABLE WORK OF REFERENCE FOR THE MECHANICAL ENGINEER, DESIGNER, DRAFTSMAN, SHOP SUPERINTENDENT, FOREMAN AND MACHINIST.

Encyclopædic in scope, thorough and practical in its treatment of technical subjects, simple and clear in its descriptive matter, and without unnecessary technicalities or formulæ. The Articles are as brief as may be and yet give a reasonably clear and explicit statement of the subject, and are written by men who have had ample practical experience in the matters of which they write.

EDITED BY

JOSEPH G. HORNER, A.M.I.MECH.E.

AUTHOR OF "PRACTICAL METAL TURNING," "MODERN MILLING MACHINES," "PATTERN MAKING," "TOOLS FOR MACHINISTS, AND WOODWORKERS," ETC., ETC.

ASSISTED BY A CORPS OF PRACTICAL MEN, EACH A SPECIALIST IN THE SUBJECT OF WHICH HE WRITES.

PROFUSELY ILLUSTRATED.

VOL. IV.

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1906.

Clack Box.—A pump chamber containing flap-valves, that open and close with suction and delivery.

Clamp, or **Cramp** (*see also* **Bar Clamp, Handscrew**).—A portable appliance for temporarily holding parts of work together. It differs from a vice in being portable, instead of fixed to a bench. It is made in many different forms, and is used more or less in almost all trades, though more in woodwork than others. With a few exceptions it has two jaws which can be adjusted in relation to each other by a screw. In a few cases, as in extemporised clamps and some simple forms in wood, a wedge is employed instead of a screw; and in flooring clamps a special form is necessary, which grips the joist and pushes against the edge of the board. In clamps for this purpose a lever is sometimes employed instead of a screw.

The simplest form of clamp is a piece of bar iron of rectangular section, with its ends bent at right angles to the body and parallel with each other. One of these ends forms a stationary jaw, and the other has a threaded hole through which the screw passes to exert pressure against the other end. This kind of clamp may be either bent to shape from bar iron, or cast in malleable iron. It is made in all sizes up to about 2 ft. between the jaws, but the sizes commonly used seldom exceed 8 in. or 10 in. Beyond that length, bar clamps are generally preferable because they do not require a screw of full length. The proportions of ordinary metal clamps are usually a depth of jaw equal to about half the length between the jaws. In bar clamps, and forms in which the screw operates a sliding jaw, the depth of jaw is much less in proportion. In clamps with no sliding jaw the end of the screw is provided with a cap or stud which does not revolve with the screw. As a further precaution against injury to the surface of the work, the stud is generally made to swivel, so that it will press flatly against the surface, even when gripping surfaces that are not parallel. In clamps used by boilermakers, the end portion of the screw is merely denuded of threads, and no stud is used on it.

Clams.—The soft temporary facings of lead, copper, wood, leather, &c., used on vice jaws to prevent injury to, or marking of the work.

Clam-shell Dredger.—*See* **Grabs.**

Clark's Process.—A successful device for softening the feed waters of boilers previous to their introduction into the boilers, which is applicable to those containing the carbonates of lime, and of magnesia. Each of these salts produces temporary hardness, being held in solution by carbonic acid gas dissolved in the water. The boiler heat will drive off the carbonic acid gas, and precipitate the carbonates in the boiler. By Clark's process they are precipitated before they enter the boiler, by the addition of lime or lime water, which combining with the carbonic acid throws down carbonate of lime in settling tanks.

The chemical reaction which takes place is expressed thus:—

$$CaCO_3 + CO_2 + CaO = 2CaCO_3.$$

In words:—

One part of carbonate of lime combining with one volume of carbonic acid gas, and with one part of lime throws down two parts of carbonate

of lime. If the lime is in excess this will form a scale in the boiler, so that it is necessary always before using Clark's process to have the feed water analysed quantitatively, and then add the exact amount of lime necessary to precipitate the exact amount of carbonate present. This amount is, according to Dr Frankland, 1 oz. of quicklime for each part of temporary hardness in 100,000 parts of water, or 700 gallons of water.

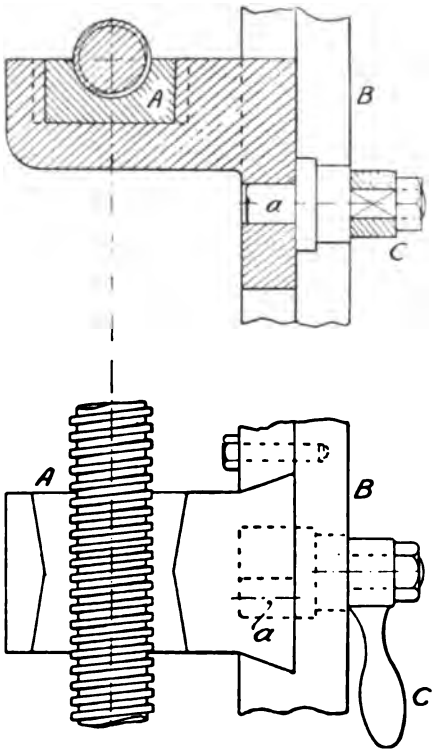


Fig. 1.—Half Clasp Nut.

When the hardness of feed water is due to the presence of sulphate of lime in addition to the carbonate of lime, then carbonate of soda, or else caustic soda, is used for the purpose of effecting a chemical interchange with the sulphate of lime. The reactions of caustic soda are as follows :—

(1) $CaCO_3 + CO_2 + NaHO = NaCO_3 + CaCO_3$.

In words :—

Carbonate of lime combining with carbonic acid gas, both soluble, and with caustic soda, yield carbonate of soda, which is soluble; and carbonate of lime precipitated.

Then :—

(2) $NaCO_3 + CaSO_4 = NaSO_4 + CaCO_3$.

In words :—

Carbonate of soda combining with sulphate of lime, both soluble, yield sulphate of soda, soluble; and carbonate of lime precipitated.

When the hardness of water is due almost entirely to sulphate of lime, the carbonate being small in amount, then carbonate of soda is chiefly used for precipitation.

Thus :—

$$CaSO_4 + NaCO_3 = NaSO_4 + CaCO_3.$$

In words :—

Sulphate of lime, and carbonate of soda, both soluble, combining yield sulphate of soda, soluble; and carbonate of lime precipitated.

Sulphate of soda is so highly soluble that it gives no trouble in the boiler. The softening effect of the carbonate of soda is accelerated by the application of heat. Complete precipitation of the lime does not take place, as shown in the equation, until a temperature of 160° Fahr. is reached.

For every 50 grains of carbonate of lime per gallon, 28 grains of lime must be added per gallon; or if caustic lime is used, 4 lb. per 1,000 gallons must be added. This will precipitate nearly 8 lb. of carbonate of lime per 1,000 gallons. The tank must be large enough to hold from six to eight hours' supply of feed water, in order to allow time for the settlement of the lime.

Sulphate of lime is found in varying amounts in all feed waters. Soda possesses the great advantage of acting on both the carbonate and sulphate of lime, and this, therefore, is the solvent and precipitant most commonly used. It should, however, be employed with discretion. That is, the first care should be to analyse the feed water, and after ascertaining the percentage of the various salts present, to proportion the amount of soda accordingly.

To precipitate carbonate of lime alone; for each grain of carbonate per gallon, $1\frac{1}{2}$ oz. of caustic soda per 1,000 gallons are required. For sulphate of lime alone; for each grain of sulphate per gallon, $1\frac{3}{4}$ oz. of soda ash per 1,000 gallons are required. When both carbonate and sul-

phate are present, the use of caustic soda will precipitate both salts.

In the proportions given of $1\frac{3}{4}$ oz. per 1,000 gallons for every grain of sulphate per gallon, it is understood that the soda is of the best quality.

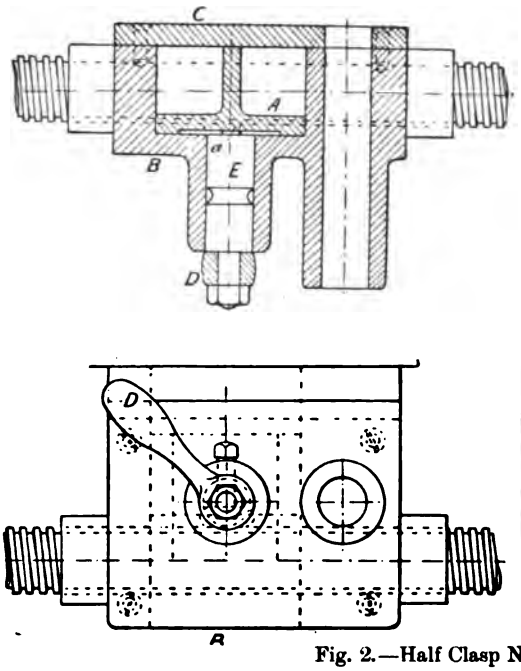


Fig. 2.—Half Clasp Nut.

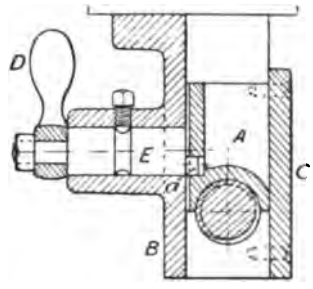
It is preferable to precipitate the salt in suitable tanks before pumping the water into the boiler. If, however, the soda is introduced into the boiler to do its work there, then frequent blowing out is necessary in order to wash out the precipitated lime which would otherwise form a hard incrustation.

Chloride of sodium must be removed by frequent blowing off.

Clasp Nut.—The nut by means of which the rotation of the lead screw of a lathe is transmitted directly to the carriage of the slide rest. It is generally, though not invariably, divided in halves in order to permit of its instant engagement and disengagement with the screw, and this is effected by a lever actuating both halves simultaneously. A few lathes have a half nut only, but this practice is exceptional. Some common forms of nuts are illustrated here.

Fig. 1 shows a very simple form used on small lathes. The half nut A, of brass, fitted with vees into a body of iron, is retained on the face of the apron B by a gib, and slid vertically by the handle C. The movement of this turns an eccentric pin *a* in a slot in the body of the nut, and so lifts and lowers the latter into or out of engagement with its lead screw.

Fig. 2 shows another design taken from a small lathe. The half nut A is enclosed, and coerced within its apron B, and a covering plate C, so that its movements are confined to the vertical direction. The handle D and pin E operate it through an eccentric pin *a* on the end of E. The eccentricity of the pin is sufficient to throw the nut down into engagement, or to lift it just clear of the thread.



In the Sellers' lathes the clasp nut bears on less than half the diameter of the screw. This is unavoidable in the design, because the screw is placed in a recess in the bed, where it is protected from cuttings. The nut is slid horizontally into and out of engagement.

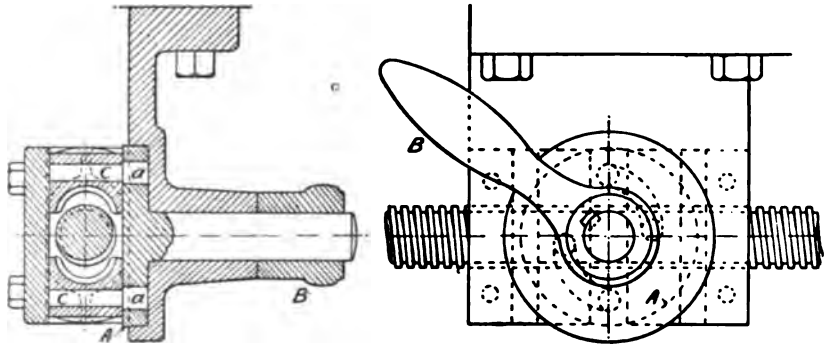


Fig. 3.—Double Clasp Nut.

A common form of double nut is shown in Fig. 3. The halves are coerced in guides, which may be differently constructed. The essential is the cam plate A, which has two curved cam slots struck from centres, so located as to give an eccentric motion to pins entering into the slots from the half nuts. The cam plate is turned by the handle B in front of the carriage, with the result that the nuts are opened or closed by the heads *a a* of their pins c c being compelled to travel in the cam slots.

The Whitworth clasp nut, shown in Vol. II., p. 23, Fig. 19, is operated by a cam plate, but there is no other resemblance between it and those just illustrated. A lever is attached to the centre of the cam plate, and is pulled or pushed by a handle coming to the front which opens or closes the clasp nuts. These are hinged, and open and close quickly.

Claw Clutch, or **Jaw Clutch**.—A clutch, the engagement of which is by interlocking jaws. There are two principal types, one being that in which both faces of the jaws are parallel with the axis of the clutch, Fig. 4, A, C, E, and F; the other in which one face only, the driving one, is parallel, the hinder face being sloped, Fig. 4, B, D. The reason for this is to permit the clutches to be thrown in at any part of their rotation. In the parallel form the jaws and spaces have to be brought opposite one another for engagement, and this may involve either slowing down, or stopping the machinery. These answer well for slowly moving mechanisms, though ill-adapted for line shafting, or heavy or rapidly moving machinery. The number of jaws in clutches of this kind varies from two, or three, A, E, to about a dozen, C, F. The spaces are made a trifle wider than the jaws

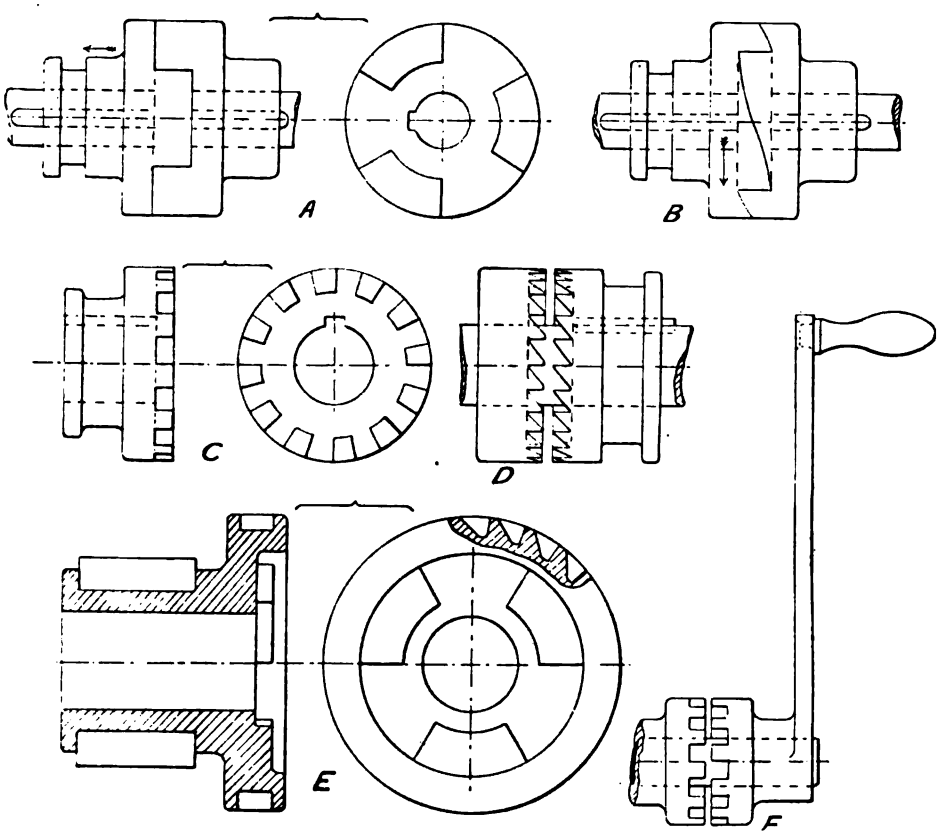


Fig. 4.—Claw Clutches.

for necessary clearance. The sides may have one or two degrees of taper, and the edges are often slightly convex to facilitate entry.

Claw clutches have their jaws cast, shaped, or milled. They may be held on the machine for tooling by their bore, or with clamping plates on the inner face of one of the flanges of the recess for the fork by which they are slid into and out of engagement. If shaped they are done with the ordinary roughing tool. If milled, edge, or end mills may be used.

Clay.—Results from the natural disintegration of rocks, and is a hydrous silicate of alumina, Al_2O_3, $2SiO_2$, $2H_2O$. The commonest varieties are Kaolin, or China clay, pipe-clay, Fuller's earth, marl, loam, brick-clay, fire-clay, and shale. Many of these are impure clays containing calcium carbonate and oxides of iron. The purest form is Kaolin, which, owing to its freedom from iron, leaves the kiln nearly white instead of red, as with certain other clays. Hence its value in the manufacture of porcelain. Cornwall is the chief source of Kaolin in the British Isles. Fuller's earth contains about 53 per cent. of silica, 10 per cent. alumina, and 24 per cent. of water; it is soft and greasy to the touch, and absorbs grease and oil. Pipe-clay is very similar to Kaolin, but contains a greater percentage of silica. Marl is a mixture of clay and carbonate of lime; the proportion of the latter ranging between 6 to 20 per cent. The common clays are invaluable for puddling cofferdams and reservoirs.

Fire-clay occurs in the coal measures, and represents the soil in which the vegetable life of the period grew. Its chief value lies in the fact that it does not fuse at exceedingly high temperatures, and so can be used for crucibles, and fire-bricks, and for lining retorts, furnaces, and converters. It is present wherever coal is found, most often occurring in beds not exceeding two feet in thickness. In England fire-clay is mostly worked at Stourbridge, in Worcestershire, and at Newcastle-on-Tyne; Stourbridge fire-clay being of such excellent quality that it is imported by other countries having less pure fire-clays in their own coal measures. It is composed of about 65 per cent. silica, 22 per cent. alumina, 9 per cent. water, 2 per cent. iron oxide, and traces of organic matter, potash, magnesia, and lime. The iron gives the clay its yellowish appearance when baked. The infusible character of fire-clay is due to the small proportions of alkaline substances and iron.

Clay Band, or Argillaceous Iron Ore.—Deposits of ore which are intermixed with clay, and occur as a ferrous carbonate, $FeCO_2$. They are distributed through the clays and shales of the coal measures of Staffordshire, Derbyshire, Yorkshire, Shropshire, Wales, and Scotland, or in the Liassic rocks. They range in colour from light grey to yellow or brown, except when weathered by the atmosphere, or discoloured by the presence of carbonaceous matters, as in the blackband ironstones.

Clay Mill.—A foundry mill used for grinding clay. *See* **Pug Mill.**

Clay Plug.—A ball of clay used to close the mouth of a riser while metal is being poured at the ingate. It prevents the rapid rush of air which would come through an open hole, with the probable result of dislodgement of cores or sand. It maintains a slight air pressure in the mould during the filling period, which should tend to soundness. The plug is not lifted until the mould is nearly filled, and often it remains until floated off by the filling up of the riser by the metal.

Clay Wash, or Clay Water.—A solution of ground clay in water, employed for swabbing the bars of moulding boxes and lifters to assist the adherence of the sand, and also as a slight cement for repairing broken sand moulds, and for pasting halves of cores together.

Cleading.—*See* **Lagging.**

Clean Casting.—This denotes a casting which has a good smooth surface undisfigured by scabs, inequalities, or apparent sponginess. A smooth surface may conceal imperfections, such as blow holes, general sponginess, and draws; and an uneven and rough surface may be possessed by a sound casting, so that superficial appearance alone may be distrusted if there are indications of possible hidden defects. Mere roughness of surface alone should never condemn a casting. The only surface roughness which is suspicious is scabbing, because that indicates almost to a certainty that the sand washed out from the scabbed part must be enclosed somewhere in the metal.

Surface roughness, which though a disfigurement, is not detrimental, is either due to lumps, or to want of suitable facings. Lumpiness, or unevenness of surface is produced by ramming done too soft, while scabbing results chiefly from too hard ramming. When the ramming is soft and irregular, the pressure of metal causes the softest areas of sand to yield considerably. There are no sharp bounding edges here as there often are in scabs, but undulated surfaces.

General roughness of surface results from not using a sufficiency of coal dust in facing sand, or from not having enough thickness of facing, and the result is direct contact of the hot metal with the sand, and the oxidation of the latter, and partial union of iron and sand.

A clean skin is much favoured by the judicious use of plumbago blacking to the surface of the finished mould. It prevents or lessens risk of sand burning, and leaves a glossy coat of plumbago adherent to the casting. But it must not be forgotten that this application does not in the least degree absolve the moulder from the need of care in other matters; since plumbago does not prevent the formation of lumps, or scabs, or blow holes, or sponginess, or render facing unnecessary. It simply ensures a clean skin with the minimum of trouble.

In steel moulds a wash of ganister takes the place of plumbago, being more refractory.

Clean Cut.—A term applied by metal turners and machinists to the action of a tool that leaves a smooth surface, instead of one having a torn-up appearance. The latter indicates that the tool is either not shaped, or else not presented properly to the work. It is a question of angles, and sometimes of lubrication.

Cleaned Mould.—A foundry mould is said to be cleaned when after the withdrawal of the pattern, all necessary mending up is done, loose particles of sand removed, and the surface dusted and sleeked with plumbago all ready for closing and pouring.

Cleaner.—*See* **Moulders' Tools.**

Clean Hole.—A hole drilled or bored straight through, without showing much mark of the drill or boring tool. To ensure this, a drill must be ground symmetrically, and not be fed at a rate beyond its cutting capacity.

Cleaning.—Smoothing the surface of a sand mould with trowel and cleaners.

Clean Lift.—Denotes the method of withdrawal of a foundry pattern from its mould. Much is involved in this, both in the construction of the pattern, and in the degree of care exercised by the moulder. Taper in suitable amount, and in the proper direction is one important element, but it is not all; since sufficient taper may be neutralised by careless lifting, or by sand insufficiently supported, or improperly rammed, or by the abuse of rapping, in starting and cracking the sand.

A frequent cause of bad lifts is in allowing wooden patterns to remain too long in the sand. It is better to let men work overtime, or when practicable to put more hands on a job to get the pattern out at night, than to let it remain in until next day. The wood swells and draws hard, especially when the lift is deep. When large patterns cannot be moulded in one day, they should be well protected with varnish or paint.

Clean lifting is often favoured by laying strips of wood around the edge of the mould, and weighting them during the time of withdrawal. These keep the sand down and prevent its fracture.

One of the advantages of machine moulding lies in the stripping plate which keeps down the sand, even though little or no taper is imparted to the pattern.

Clean Metal.—Molten metal which is free from dirt of all kinds, as scale, scurf, oxide, and foreign intermixtures.

Metal in the course of melting takes up mechanically particles of other materials in the furnace, and gives off oxide and scoriæ. To get rid of these, melting must be perfect, and then the foreign matters rise to the surface, whence they can be skimmed off. To facilitate this, hot metal is allowed to stand in the ladle for a little while before pouring, being skimmed at intervals as fresh scoriæ rises to the top. In sending up the lighter matters to the surface it cleanses itself, only it must have excess of heat in the first place, or it would become too thick for pouring. It is in this thorough or dead melting, followed by a period of quiescence and skimming, that the secret of clean metal lies.

Clean Scrap.—Broken castings which are not composed of inferior burnt iron; or forged scrap from which traces of cinder and scale have been removed.

Clean Thread.—A screw thread which is left smooth and sharp instead of being roughened up by the act of cutting.

Clean Water.—Feed water for boilers free from mud and sediment. This does not touch the question of chemical composition.

Clearance. — Signifies leaving a space between adjacent portions of mechanism. It is applied both to rough and machined work, the first named being larger in amount than the latter. The subject will be found treated under **Limits**, and **Gears.**

Clearing Hole.—A hole made slightly larger than the bolt or pin which has to pass through it. It generally relates to a hole which is cored.

Cleat.—*See* **Battens.**

Clements' Driver.—*See* **Driver.**

Cliff Railways.—Inclined tramways, as distinct from rack railways. They are short, but steep, and the cars are actuated by water, the gravity of which in the upper descending car draws up the lower ascending one, the cars being connected by two cables of wire rope passing round a pulley of several feet in diameter. The lines are double to permit of ascending and descending cars passing one another. The water is contained in a storage reservoir at the upper terminus. Sometimes there is one at the bottom also when the water supply is costly, and then the water is used over and over again. Tanks are placed under the floors of the cars. These tanks are filled with valves controlled by the conductors, who have electric communication with each other. The quantity of water is regulated to suit the number of passengers in the lower and upper cars. When down traffic predominates, little or no water is used, the weight of passengers sufficing to haul up the lower light car.

Safety is ensured by having a large margin of about ten for the wire ropes, and by fitting the cars with brake shoes, the normal condition of which would be that of pressing on the rails. The conductor holds the brakes off by raising a weight from the water in an accumulator, the pressure of which is obtained from pumps worked by eccentrics on the wheel axles. When released the brake shoes grip the rail. Other supplementary safety appliances are provided.

The Clifton Rocks Railway runs through a tunnel, the Lynton and Lynmouth, the Bridgnorth, and Aberystwith are in open cuttings.

Clinkering.—Cleaning out the hard cinder from the furnace grate of a steam boiler periodically. It should be done at least once a day.

Close.—Is applied to a short-link chain, to a fine grain of timber, or of metal, to the mouth of a shearing machine that will not admit a long bar, and to the modern close-topped blast furnace.

Closed Ashpit.—In Howden's system of forced draught, air is blown by a fan into a tight casing, attached about the boiler front, and is admitted under the grate, the ashpit being otherwise closed from the outer air. A passage for air is also provided, so that secondary air to burn the gases from bituminous coal may enter above the fire, and means are provided to shut off the air supply when the fire doors are opened. This system is much simpler than the closed stokehold system, and it is much more easy to manage. Less excess of air gets through the furnaces when the doors are open, and altogether the system is more convenient. By its means the output of a boiler may be forced to its safe maximum, and the closed ashpit has therefore been widely applied in merchant steamers.

Where the air supply of a boiler is heated, and its volume increased, it is not possible to get the same weight of air into a furnace in a given time as when colder air is employed. By any system of forced draught this difficulty is overcome, the air being heated preferably between the fan and the furnace, so that the fan may work in cold air with a maximum efficiency. The closed ashpit system has been much employed in various forms for the burning of inferior fuels. The benefit of forced draught arises almost wholly from the greater rapidity of combustion due to the more energetic inflow of air through the grate. Very little effect is produced by the greater density of the

air, which is but very slightly more dense than at ordinary atmospheric pressure. *See* **Closed Stokehold, Forced Draught.**

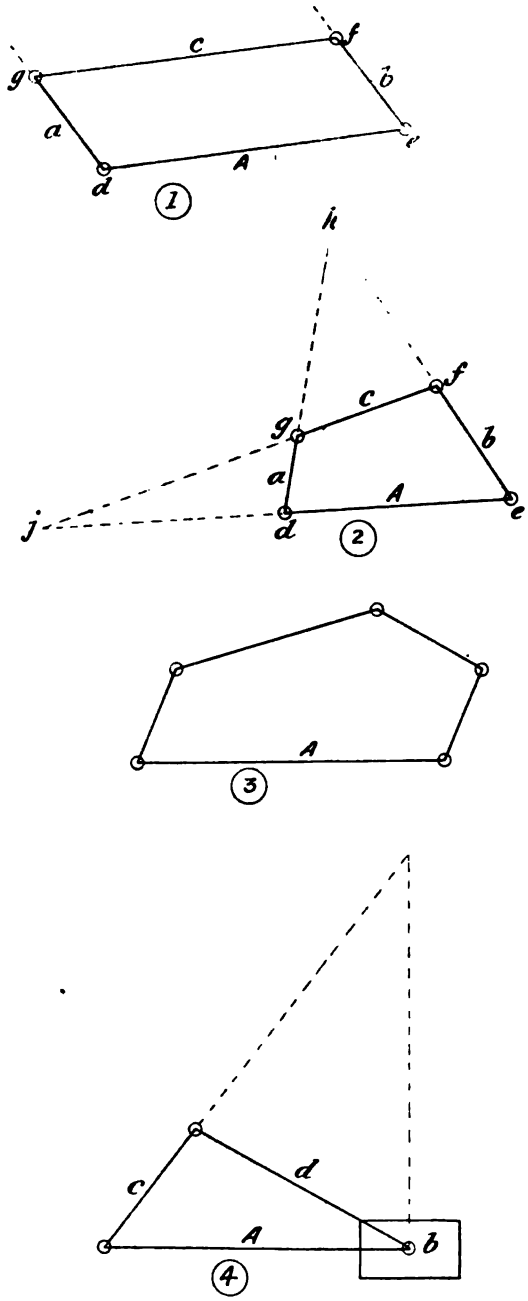


Fig. 5.—Link Work.

Closed Chains.—A term due to Professor Reuleaux, to denote a series of mechanical links which are completely paired or connected, so that each link is constrained absolutely by the pair of elements to which it is connected. Some essential elements of link work are here illustrated, Fig. 5, which, variously modified have their applications in an almost infinite number of mechanisms. Each set of links differ essentially from the others, though they do not appear to be very dissimilar. In each case the link A is a fixed one.

The first, Fig. 5 (1), is a parallelogram or double-crank mechanism, the links *a*, *b*, *c*, pivoting round *d*, *e*, *f*, *g*, forming *turning pairs*. Such a combination is capable of numerous applications, and the centres of the links being inaccessible, are *instantaneous centres*.

The next (2) is a combination in which the links, lettered as before, turning about their fixed centres, have their instantaneous centres at *h*, for the link *c*; and at *j* for the links *a* and *b*. The centres *d*, *e*, about which *a* and *b* rotate, are fixed, and every point in *a* has the same angular velocity round *d*, and every point in *b* the same angular velocity round *e*.

The next diagram (3) shows an impossible mechanism, because the interposition of an extra link prevents that constrainment of adjacent pairs, which is necessary to properly directed motion.

The diagram following (4) contains a sliding pair A *b*, in addition to the turning pairs *c*, *d*. This will be recognised as the piston, connecting rod, and crank of the steam engine, and similar mechanisms, and is an example of the *slider crank chain*. By the aid of these figures the difference between the instantaneous and permanent centres can be illustrated.

In (2) the motions of the links *a*, *b*, and *c* are constrained, so that neither can move without the other. The centres *g* and *f* are both permanent and virtual centres. But there are two other virtual or instantaneous centres in the mechanism, *h* and *j*. As the axes, or virtual radii of these last centres are situated at right angles to the tangent of the arc of movement at any instant, it is only necessary to project the axes of non-adjacent links until they join in the instantaneous centre *h*, for A and *c*, and *j* for *a* and *b*. This is clear from the following reasoning:—

The link *c* is connected to A by the links *a* and *b*, and its motion is thus constrained; for *a* and *b* move with definite angular velocities round *d* and *e*; *c* is coerced by the centres *f* and *g*, which are points in *a* and *b*; and these centres *f* and *g* must have the same motion relatively to A as points of *c*. In other words, there are two points known in *c* relatively to A, and therefore the axes *a b* projected through *e f*, *d g* meet in the virtual centre *h*, and the axes projected through *e d*, *f g* meet in the virtual centre *j*.

Closed Pass.—A pass in rolls used for producing steel sections, in which the bodies of the rolls touch each other at the sides, and prevent the squeezing out of fin. The groove cut in the lower roll is flanked by collars of large diameter, and these collars fit into grooves in the upper roll.

Closed Stokehold.—To increase the duty of a boiler the draught may be intensified mechanically either by an **Induced Draught** Fan, by a **Closed Ashpit** System, or by a Closed Stokehold, into which air is forced by a fan. The system, though tried by Stevens in 1846, and adopted by Isherwood on gunboats, was in later years introduced first on torpedo boats by Thornycroft, who at first tried to burn as much as 225 pounds of coal per square foot of grate per hour, with 10 inches of water-gauge draught pressure.

The system consists simply in enclosing the boilers in an air-tight room into which a fan forces air. The combustion that may thus be reached is very rapid, but a limit is put on the draught pressure by the physical ability of firemen at sea to keep pace with the combustion. While with ordinary draughts about 10 pounds of coal per square foot of grate may be burned per hour for each $\frac{1}{4}$ inch water-gauge, this rate with forced draught was not at first reached, though in later vessels it has been nearly approached. About a fourth of a horse power was found to be required per square foot of grate surface in the French ships *Hoche*, *Marceau*, and *Magenta*, burning at the rate of 50 lb. per square foot.

The difficulties of the system are that the fire room, or stokehold must be entered through a double door, or air lock, and men felt themselves as it were shut in dangerously. In the L. & N.W. *s.s. Cambrian* a heavy flap door was provided for escape if required. A further objection is that when a fire door is opened there is a great rush of air through the furnaces, with corresponding chilling effect, and means should be provided to close a damper to each boiler upon opening the fire door, as otherwise there is great loss of air. The system enables a very large additional power to be got from the same boilers when the draught is forced to about $1\frac{3}{4}$ inch water-gauge, with a consumption of about 50 lb. of coal per square foot per hour, but the coal used per horse power is greater. Probably with thicker fires and precautions against loss of air when the fire doors are opened there would be a better result, and it is probable that much better results would be got if the grate area were reduced as the draught was increased, in place of forced draught being employed merely to increase the duty of a given size of boiler.

It has not so far been found so easy in practice to employ so high a rate of forced draught as of induced draught. In locomotives the vacuum in the smoke-box may be as high as 10 inches, yet there is little furnace or tube trouble with locomotive boilers. But there is little or no apparent reason for the difference, unless it be that with the closed stokehold there are such heavy chilling effects produced when the furnace doors are opened, when no proper provision is made to combat this rush by dampers. *See* **Closed Ashpit.**

Clothing.—*See* **Lagging.**

Clutch.—An agent by which connection is rapidly made and broken between lines of shafting, trains of gears, or different sets of mechanism. From the simple claw clutch many designs have developed. The cone or taper friction clutch is the most common, then come various special forms of friction clutch, as the Weston, the expanding, the coil clutch. There are also some clutches that disconnect automatically. And there is the magnetic type. Each of these will be found described under its own title.

Coal.—The most valuable of the fuels used in engineering has been produced by the decomposition of vegetable matter. It consists mainly of carbon, the percentage of this element ranging between 60 per cent. in the brown coals, to 95

per cent. in anthracite. The remaining constituents are hydrogen, oxygen, nitrogen, and sulphur, with silicates of alumina and iron found in the ash. The rank vegetation which flourished in the moist and warm climate of the carboniferous period has, while entombed in the earth, undergone a series of complicated chemical changes, the final result of which has been to increase the relative proportion of carbon from about 50 per cent. to 90 per cent., to reduce hydrogen from 60 per cent. to 30 per cent., and nitrogen and oxygen from 40 per cent. to 3 per cent. The different kinds of coal are classed as:—(1) Lignites, (2) Bituminous coals, (3) Anthracites.

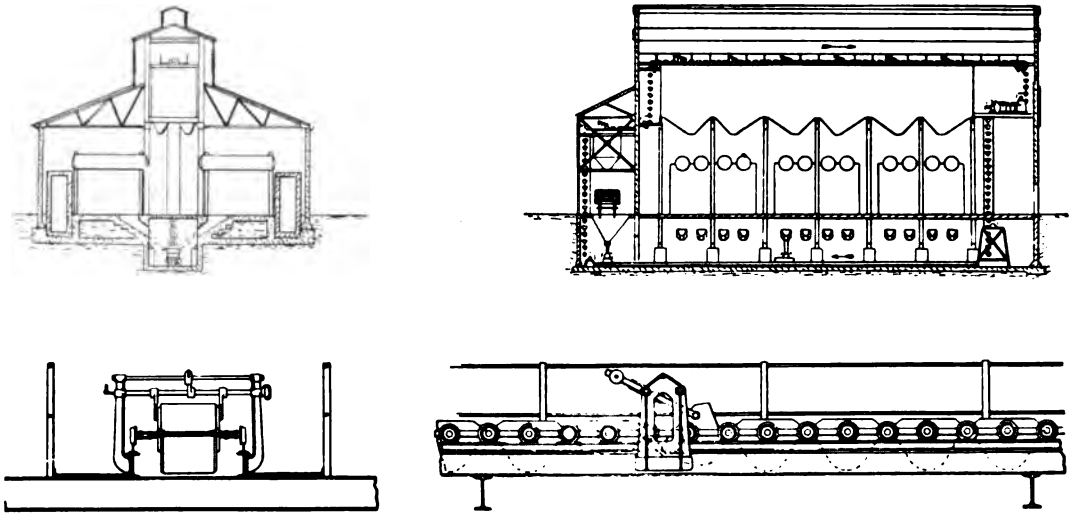


Fig. 6.—Gravity Bucket Conveyor for dealing with Coal and Ashes for a Battery of Steam Boilers. (Spencer & Co., Ltd.)

The *lignites* or *brown coals* are of more recent formation than the other two classes, the texture of the wood being frequently visible. Containing but 60 to 70 per cent. of carbon, lignite is of very little value as a fuel. This coal gives little heat and flame, but much smoke.

Bituminous coals occupy an intermediate stage in the process of mineralisation between lignites and anthracites. The percentage of carbon is higher in this group. Though inferior to anthracite and steam coal, bituminous coal is used for steam raising, but is chiefly valued for domestic purposes. This class is divided into caking and non-caking coal. The former yield much smoke, gas, and flame, and swell up into a spongy mass when burning, although their chemical composition is practically the same as that of the non-caking coals. A mixture of these two classes is sometimes advisable, or it may be necessary to use a caking coal as a bed for a non-caking kind. Gas, coking, furnace, and cannel coals belong to the bituminous class of coals. Gas and cannel coals yield large quantities of gas on distillation, the latter giving from 8,000 to 15,000 cubic feet per ton.

Anthracite is almost entirely pure carbon, the best kinds having but 2 or 3 per cent. of other matters. It is more difficult to light than other kinds, but when ignited it gives off very intense heat with scarcely any flame or smoke. *See* **Anthracite.**

The following table shows the average percentage chemical composition, and specific gravity of various coals.

Locality.	Sp. Gr.	Carbon.	Hydrogen.	Oxygen.	Nitrogen.	Sulphur.	Ash.
Wales -	1·315	83·78	4·79	4·15	0·98	1·43	4·91
Newcastle	1·256	82·12	5·31	5·69	1·35	1·24	3·77
Lancashire	1·273	77·90	5·32	9·53	1·30	1·44	4·88
Scotland -	1·259	78·53	5·61	9·69	1·00	1·11	4·03
Derbyshire	1·292	79·68	4·94	10·28	1·41	1·01	2·65

Coal Conveying Plant.—During recent years this plant has been developed to an amazing extent, displacing the slow and costly hand-barrows and trucks, shovels and skips from all establishments where the least consideration is given to economies. These plants are not of a hard and fast character, but are of protean types modified to suit all conceivable conditions. The **Bridge Crane**, whether used as a single unit, or in the form of tramway plants, is a conveying system in itself. Generally some form of bucket, or belt conveyor, or plate conveyor, or cableway is embodied for hoisting, travelling, and dumping, or storing coal. Direction of movement is provided for readily, the conveyors being inclined at any angle, or running horizontally. Automatic filling is accomplished by hoppers or by fillers.

Fig. 6 illustrates a good example of one type of coal conveying plant for a battery of steam boilers. The boiler house is shown above, and the gravity bucket conveyors to an enlarged scale below. The chain of gravity buckets, driven round by gear situated at the upper right-hand end of the building, receives coal from a hopper seen at the lower left-hand end, fed by a railway truck above. The buckets travelling round in the direction of the arrows are tipped over the various bunkers by the tripping levers seen in the lower figures. These can be set to engage over any bunker. Ashes are discharged through inclined shutes seen in the upper figures, under the boiler room floors, thence conveyed to a hopper above the line of rails, and discharged into trucks.

Fig. 7 shows an elevating and conveying plant for slack coal, feeding three gas producers, and having a capacity of 20 tons per hour. The coal is fed through a hopper, the mouth of which is on the ground level, whence it is lifted by the inclined bucket conveyor, and carried along horizontally by a screw conveyor, and so dumped into the producers.

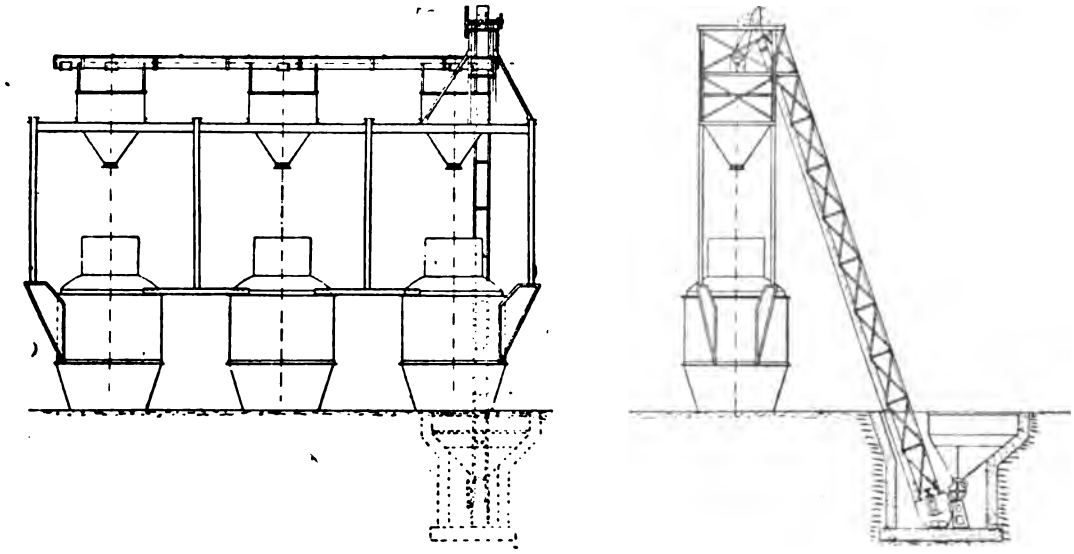


Fig. 7.—Coal Elevating and Conveying Plant for Feeding Gas Producers. (Spencer & Co., Ltd.)

Coal-Cutting Machines. — Coal-cutting machines are designed to perform the operation known as holing, or undercutting when done by hand labour. Coal seams lie wedged between the strata above and below them, so that space has to be made to enable the coal to be removed. This is accomplished sometimes by cutting away the underlying strata, sometimes the coal itself, and sometimes where there is a dirt parting between two seams of coal lying very close together, this is removed. The hewer,—the hand

holer, removes a sufficient quantity of the coal or other strata with his pick, gradually working his way underneath the seam for the purpose. The coal is if possible undercut to its breaking depth, *i.e.*, the depth at which the undercut portion will fall away from the solid. This breaking depth varies in different seams with the character of the parting between the coal and the stratum immediately above it, and thus may be from 3 feet up to 6 feet. The coal hewer cuts a groove, the section of which is a right-angled triangle, because he is obliged to cut sufficient of the front portion of the coal away to allow his shoulders to go under while he swings his pick.

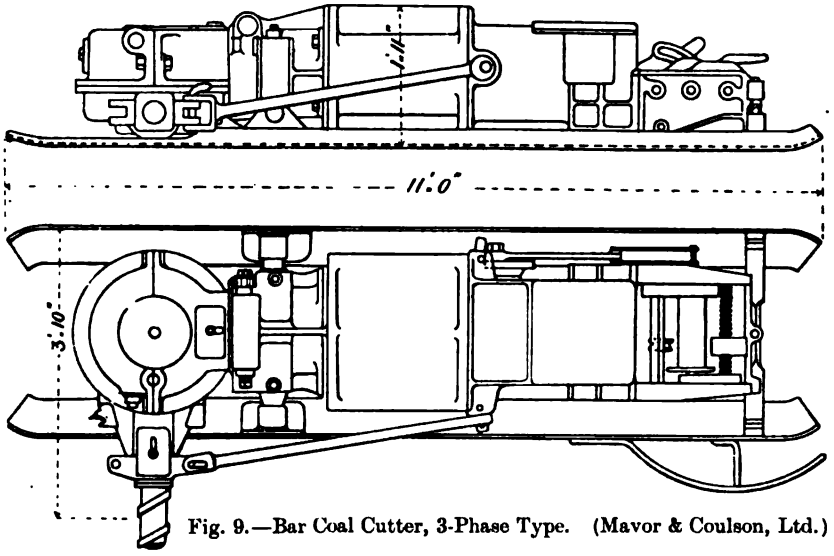


Fig. 9.—Bar Coal Cutter, 3-Phase Type. (Mavor & Coulson, Ltd.)

Types of Machines.—The coal-cutting machine cuts a parallel groove, to the required depth, and in some cases has enabled the management to dispense with or to lessen the blasting that is otherwise necessary to force the coal away from the other strata. Coal-cutting machines are of five types, illustrated in succeeding figures, the *disc* machine, the *bar* machine, the *chain* machine, the *percussion* machine, and the *rotary chain heading* machine. The disc or wheel, Fig. 8, Plate I., carries cutting tools on its periphery, which cut and scrape the coal or dirt away as the disc revolves. The latter rotates in a horizontal plane, on a vertical axis. The bar type, Figs. 9 and 10, carries cutting tools arranged all round its circumference, and along a portion of its length. It revolves in a horizontal plane, on a horizontal axis. The chain, Fig. 11, Plate I., carries cutting tools fixed in some of its links, and is supported by a frame, which in one form is forced under the coal in front of the machine, and in another type is turned round at right angles to the body of the machine. In both cases the chain is kept in motion when the machine is working; the cutters chipping, or scraping away the dirt or the coal as it runs.



Fig. 10.—Bar for above Machine.

In these machines power is sometimes provided by a two-cylinder compressed air engine, and sometimes by an electric motor. The latter is gradually gaining ground as the use of electricity is becoming more and more common in coal mines, and because the quieter electric drive gives the miner a better chance of hearing the warning sounds when the roof is threatening

to fall. All the above, except one, are used for longwall work, and in all, with that exception, the machine includes a small haulage drum, driven by gearing from the motor, on which a wire rope is wound, which hauls the machine along the coal face as it cuts. The exception is the chain heading machine, which is only used for driving headings, or roads in this country, and in America for their modification of pillar and stall working.

The chain heading machine, Fig. 11, Plate I., is moved up to the coal face, and at right angles to it; the frame carrying the chain is pushed gradually under the coal as it cuts; and after the cut is finished, the frame is withdrawn, the machine moved bodily its own width to the right or left, and another cut made, and so on till the proper width has been holed, when it is moved to the next stall, or run back out of the way till that piece of coal has been got down.

The percussion machine is different from either of those described above. It is sometimes called the pick machine, and consists of a single tool, really a large percussion drill, attached to the piston rod of a compressed air cylinder. The whole is mounted on a carriage, behind which the miner crouches, special chocks being fitted to his boots to enable him to keep the machine up to its work. It operates exactly like a percussion drill, but is used to chip away the coal or other strata, just as the coal miner does, and the groove made is very similar, not parallel like that made by the other machines. There is another adaptation of the percussion rock drill that has developed into a coal-cutting machine, in which the drill is fitted on a support, with a universal joint, attached to a pillar that can be fixed anywhere at the face of the coal. The drill works in arcs of a circle, the radius of which may be increased by fixing longer and longer drills. The machine can cut at any angle, from the vertical to the horizontal, and is therefore useful for "nicking," *i.e.*, making the vertical cut required with narrow work.

There is one more machine, known as the Stanley rotary heading machine. It is the only one of its kind, and its office is to cut roads or headings. It has cutting tools carried by holders at the ends of a long bar forming the diameter of a circle, the centre of which is attached to the driving shaft of a double-cylinder compressed air engine. As the engine revolves, it drives the arms round with their cutting tools, an annular groove being cut in the coal, leaving a solid core which is got down by blasting in the usual way, the annular groove providing the room for the core to break up. Two machines are sometimes used side by side. The machine is employed principally when a colliery is being opened out, to cut the main roads. A modification of the machine is made in which the core is cut up into small chips, and delivered by a conveyor at the rear of the machine. The machine is also arranged to be driven by an electric motor. No haulage gear is necessary with this machine, but it is fed onwards, as it cuts, by the usual feeding gear. The *modus operandi* is this:—The machine is brought up to the face of the coal that is to be cut, fixed in position, the arms revolved, fed out to their full extent, then run back, the machine got back out of the way, while the core is got down, and run up again to the new face when it is ready.

It is to the longwall system of coal cutting, the only method by which thin seams can be cut, that the development of the machine system is due. For thick seams, and for the pillar and stall system, machines do not show to so much advantage as in those of medium thickness.

The Jeffrey longwall disc coal cutters are made to run with two wheels on a single rail, which simplifies the rail laying, and diminishes strains in the machine which arise in consequence of double rails being out of level. They are operated either by electricity or compressed air, with corresponding differences in the details of their construction.

In the electrically driven type the motor is situated at the centre of the machine, and drives through cut steel gearing, enclosed in an oil-tight casing, to the disc pinion shaft. This enclosure reduces noise, and is thus an element of safety by giving the men warning of cracks. The speed of the feed can be varied while the machine is in motion, from 0 to 25 in. per minute. The discs are made to undercut from 3 ft. 6 in. to 6 ft.; those of 4 ft. and upwards being split to permit of their easy handling. The disc is cast with a grooved rim, into which the tool holders

are riveted. The cutters are straight, and the necessary width of cut is obtained by fitting holders, some bent upwards, some downwards, and some straight.

The Diamond chain machines for longwall working are driven by compressed air, or by continuous or polyphase electric motors of 10 to 15 BHP., wound to suit any voltage from 200 to 600. The motors are enclosed in gas-tight casings, and combined starting and reversing switches are fitted. The standard size holes are 5 ft. 6 in. deep, by 5½ in. in width, and at any height from the floor level to 3 ft. 6 in. above the floor; running also in either direction, but machines are also made for depths of 7 ft.

Disc v. *Chain Longwall Machines.*—One advantage claimed for chain machines for longwall working is, less weight is required to balance that of the tool carried, and hence the total weight being smaller, transportation is easier. It is also claimed that it is easier to clear away the debris than with the disc machine. In making comparisons between machines of different types, it must be remembered always that no single machine is adapted to all conditions, but each finds its most appropriate place, and is successful where others would fail.

An advantage claimed for the chain machine is that it is not so liable to become wedged as the disc, and that the debris can be cleared out more easily. They have been used to a great extent in America.

In the Hopkinson chain machine, Fig. 11, Plate I., of British manufacture, a very strong Renold chain is used, and the forged cutters are held in hinged cutter boxes, in which they can be easily changed. The jib that controls the movements of the chain can be slewed to an angle of 180°, which renders it capable of cutting into the coal at the start, without the need for excavating a stable, as for a disc. The jib can be lifted and carried by two men. The driving mechanism is compact, and narrow. The machines will undercut 6 ft. 6 in., and 4 ft. 6 in. respectively in the two standard sizes made. The feed gear is a steel worm, and phosphor-bronze wheel, with an adjustable crank, and pawl and ratchet. The motor is of the four-pole type, entirely enclosed in a flame-tight casing. The switch and resistance are of tramway type, completely immersed in oil to prevent sparking at the contacts.

The Jeffrey chain header, Fig. 12, Plate I., for pillar and stall work has the chain composed of tool holders and links, and runs round the front end of a movable frame on two idler sprockets. The feed is at the rate of about 6 feet in 3½ minutes, and the return is done in about a minute and a half. The feed may be made as low as 6 feet in seven minutes. The movable frame is moved forward by two pinions in racks fixed on a stationary frame; the latter is provided with two jacks having hand-wheels on screws. The one in front is fixed against the coal, and set at an angle to prevent the tools from running across the coal face, and thus slewing the machine; the hinder jack is set against the roof, so jamming the frame in its proper position to guide the cut. The machines will undercut to a depth of 5 feet, 6 feet, or 7 feet, with a width of 3 ft. 8 in., and a thickness of 4¼ in. These are made to be driven electrically, or by air.

Jeffrey electrical coal drills occur in varied designs. The frame is made in different lengths to suit the various seams, and at its upper end there is the hand-wheel for fixing it between the pavement and roof, Figs. 13 and 14, Plate I. The screw allows for a variation of 8 inches in the height. The body of the drill can be mounted on trunnion brackets with hinged lids to be readily unshipped for moving about the pit. The brackets slide up and down the sides of the frame. The drill can be set in any vertical direction within a range of more than 90°. The thrust is taken by a ball race on the front of the machine. A slipping clutch is provided. The motor is series wound. A hole 2 inches diameter and 6 feet deep can be drilled in coal in about 2½ minutes. Fig. 14 is a similar drill driven by compressed air.

Value of Machines. — The advantages of machines are as follows:—A straight line of cut, against the sinuous one left by the pick. An increase of output, with corresponding economy in wages. The men work in an upright position, instead of lying down, and accidents are lessened. Spragging is more



Fig. 8.—Disc Coal Cutter.
(Clarke, Steavenson, & Co., Ltd.)



Fig. 11.—Hopkinson Chain Coal Cutter.



Fig. 12.—Jeffrey Chain Header. (John Davis & Son, Ltd.)

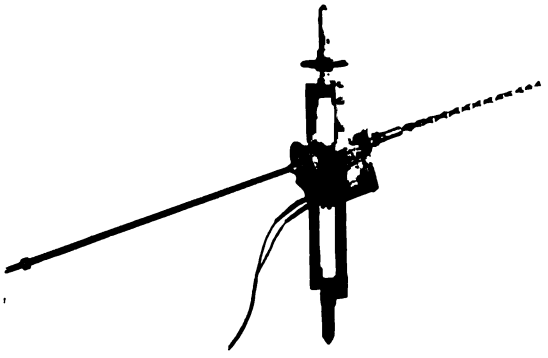


Fig. 13.—Jeffrey Electric Coal Drill.

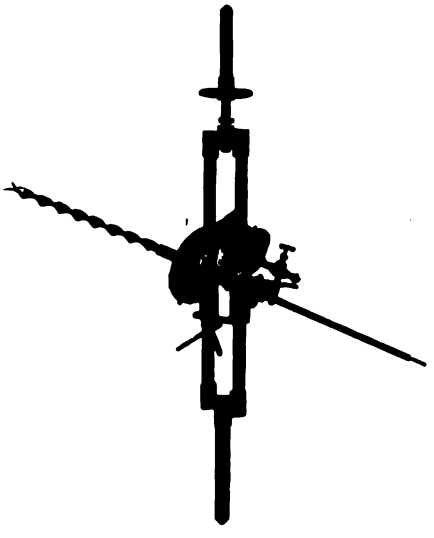


Fig. 14.—Jeffrey Pneumatic Coal Drill.

(John Davis & Son, Ltd.)

To face page 16.

readily done against the flat surface left by a machine cut than against the sloping face left by the pick. The use of shots and explosives is lessened. The excavated coal is removed before the roof pressure comes on, and less small coal is made than with the pick. There is also saving in timber, and greater tonnage obtained.

It is an advantage to a machine to be able to hole to varying depths, or from 4 ft. to 7 ft. to suit any particular seam. The cut must be of sufficient height to cause complete fracture between the excavated and solid coal to take place, so that the subsidence of the roof shall not crush or wedge the coal. Nearly noiseless action is desirable, so that indications of the giving way of the roof may be heard by the men, who should be able to converse close to the machine. Machines should also run in either direction. Though a light machine is desirable for portability, mass is more essential, because it must serve as its own foundation, and be able to assist the work of cutting, to produce a straight cut, and to withstand sudden strains, and be without vibration. The driving power must also be in excess, and only compressed air and electricity are suitable for mining.

Coal-cutting machines have been in use for thirty years or more. Twelve years ago the depth of cut did not exceed from 2 ft. 10 in. to 3 ft. 6 in. Now in special cases it reaches to 7 ft., but 5 ft. 6 in. is more within the range of ordinary requirements. Machines show to greater advantage when operating on a long face. For short faces the cost of transporting the machines is heavy. Coal faces of from 1,000 to over 2,000 ft. in length have been cut; one case has occurred of a face 4,800 ft. in one straight length.

Coalfields.—Geologically we are indebted for the rich strata of our coalfields to the coal measures of the Carboniferous System. Fortunately this system is very strongly developed in our islands, and we draw our supplies of coal and other minerals from some thirty districts.

In England and Wales the leading coalfields are in South Wales, Northumberland and Durham, Yorkshire, Derbyshire and Nottinghamshire, Cumberland, Lancashire and Cheshire, North and South Staffordshire, Forest of Dean, and Bristol. In Scotland, coal is found in Fifeshire, Stirlingshire, Lanarkshire, and Ayrshire. In Ireland, in Tipperary and Kilkenny. In other parts of the world coal of carboniferous age is found in the coalfields of Belgium (Liége, Charleroi, and Mons); Saarbrück, Hanover, Silesia, Saxony, and Westphalia, in Germany; St Etienne in France; and Donetz in Russia. Other rich coalfields exist in China, North and South America, Japan, South Africa, and India. Carboniferous strata are also found in the Arctic regions. North America is particularly rich in coal, the total area of her coalfields being estimated at over 200,000 square miles. Both England and the United States export large quantities of coal to Europe, and Welsh steam coal is used in all the great navies.

Coal itself forms only a small fraction of the strata of a coalfield. Ores of iron, zinc, lead,

MECHANICAL COAL CUTTERS EMPLOYED IN THE UNITED KINGDOM IN 1904.

Kind of Machine.	Number in Use in the Various Districts.												
	East Scotland.	West Scotland.	Newcastle.	Durham.	York and Lincoln.	Manchester and Ireland.	Liverpool and N. Wales.	Midland.	Stafford.	Cardiff.	Swansea.	Southern.	Total.
Disc	54	77	25	44	140	22	60	80	11	2	...	1	516
Percussive	...	7	17	16	16	19	30	8	6	2	...	1	122
Revolving bar	7	2	3	11	5	4	1	17	4	5	...	1	60
Rotary "heading"	10	...	...	...	...	...	...	13	...	...	...	...	23
Toothed endless chain	4	9	2	2	4	1	...	11	1	...	...	...	34
Total in 1904	75	95	47	73	165	46	91	129	22	9	...	3	755
Total in 1903	56	73	43	61	158	35	77	108	24	2	3	3	643

and antimony abound; fire-clays, sandstones, and limestones are present in varying quantities; shales of different qualities occur. The quality of the coal varies, too, in different coalfields, and hence serves different purposes. *See* **Coal, Anthracite, Bituminous Coal,** &c.

The coal measures vary in thickness from 10,000 feet in South Wales to 6,000 feet in the North of England, and 2,000 feet in Scotland. The coal seams, however, measure but a fraction of this depth, and may varv in thickness from a few inches up to 30 feet, and in some cases even more.

A Royal Commission was appointed in 1901 to inquire into the extent and resources of the coalfields of the United Kingdom. The report was issued in 1905. The Commissioners hesitated to prophesy as to the probable duration of our coal supplies, but considered that the average increase in the output, 2½ per cent. per annum, during the past thirty years, could not be maintained. The present annual output is over 230,000,000 tons; the available resources in the proved coalfields, as calculated by the Commission, equal 100,914,668,167 tons; while probably another 39,483,000,000 tons lie in the concealed and unproved coalfields.

Coal Mill.—A mill used for grinding coal for mixing with facing sands in the foundry. It is either one rolling horizontally with loose rollers, or a form of ball mill, a couple of balls being revolved in an annular bed of semicircular section.

Coal Mining.—Coal mining is the art by which the coal, which has been formed by Nature's operations during millions of years, and at various depths below the surface of the earth, is brought up and placed on the market. Coal lies in seams which are spread out like irregular sheets, of thicknesses varying from a few inches to 10 yards, and it lies almost always in basins, of irregular shape, the seam of coal coming to the surface, or "out-cropping" at each side of the basin, and sinking lower as it recedes from the outcrop.

There are two principal methods of getting to the coal; by shafts, and by what are called in different districts, "slopes," "levels," "drifts," &c. In all of these latter, a road or tunnel is run into the side of a hill or mountain, meeting the coal at a certain distance from the surface. With shafts, which are employed where the depth of the seam is too great to reach it by a road from the surface, two are sunk close together to the seam. Usually the shafts are arranged to meet the seam at its highest point within the area to be worked, as it is cheaper to follow the seam down by inclines, than to sink the shafts to lower levels. From the shafts and from the levels, the coal is followed to the boundary of the area for which the lease is taken.

There are two principal methods of working the coal, the "*Long Wall*," and the "*Bord and Pillar*." The latter is often called "*Stoop and Room*," and "*Pillar and Stall*." It is the oldest method. From the shaft two main roads are run out to the boundary. From these, roads are run at right angles, and again other roads at right angles to them, till the whole area is divided up like the squares of a chess board. The roads, which are cut as the opening out of the mine progresses, represent the area of coal that is taken out at first. When the boundary is reached, and what is called working back commences, the pillars which have been left to support the roof are removed, commencing from the boundary and working towards the shafts.

In the "*Longwall*" method, which has come into use more since the lower and smaller seams have been worked, the whole of the coal is taken out as the workings advance. A long wall or face is formed, which moves continually forward, the roof behind being allowed to settle down upon rubbish packing, after the coal has been removed, as the face moves on. In a large mine there will be several faces moving towards different parts of the boundary. In some cases the roads are driven to the boundary, and the coal is taken out on the Longwall system, commencing from there and working towards the shaft. There are various modifications of both Bord and Pillar, and Longwall that have been developed for different coalfields, and there are special methods of working the very thick coals of Staffordshire and elsewhere, to enable the largest proportion to be obtained. The roads that are formed act as travelling roads for the men, as haulage roads for the mine wagons, and as ducts for the air which is required to ventilate the mine. Air enters the mine by one shaft, the *Downcast*, and traverses all the workings; being led to them from one of the main roads mentioned, the *Intake;* and

returns to the surface by the other shaft, the *Upcast*, being led to it by the other main road, the *Return*. *See* **Coal-cutting Machines.**

Coal Tips.—Denotes a special group of hoisting and discharging machines for coaling vessels. Though they are subject to many variations in detail, their general functions can be gathered from the design of the installation by Messrs Fielding & Platt, Ltd., at Penarth docks, and illustrated by the photo, Fig 15, Plate II., and drawings, Figs. 16 and 17. These are actuated hydraulically. Electric driving is begin ning to come into rivalry with pressure water, and some ordinary cranes have coal-tipping arrangements. Besides these there are the big coaling cranes, and at the other extreme the long-armed bridge cranes, which, however, fulfil also the functions of transporters over considerable distances. The cardinal distinction between the coal tips and bridge tramway plants is that the first handle heavy units, the second light ones. But as the latter travel at high speeds the sum total of work done in a given time may often amount to the same.

The hydraulic tips illustrated take a 10-ton wagon load of coal, lift it 45 feet, discharge it into the shoot, and lower the empty wagon on the quay; the cycle of operations occupying sixty seconds. The lifting cradle is actuated by four rams,

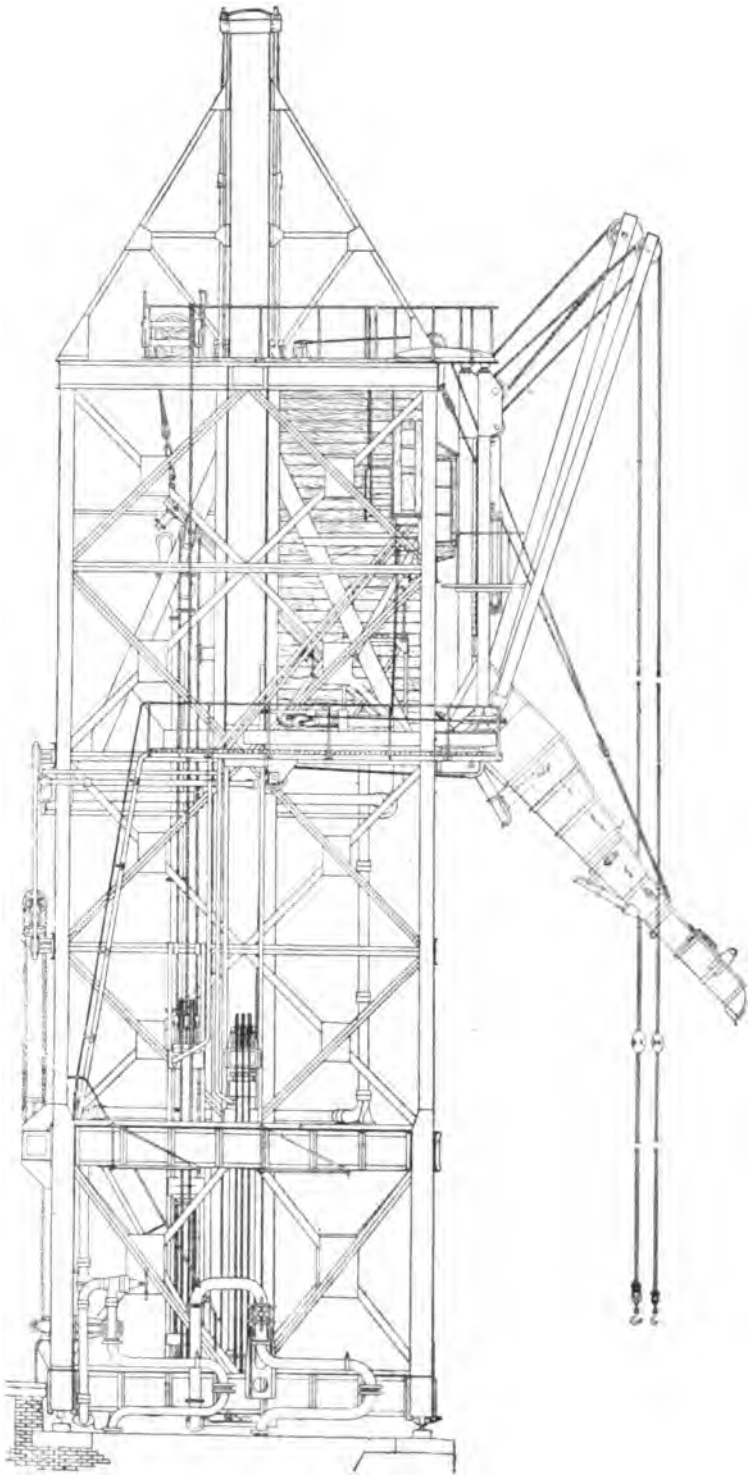


Fig. 16.—Hydraulic Coal Tip. (Side Elevation.)

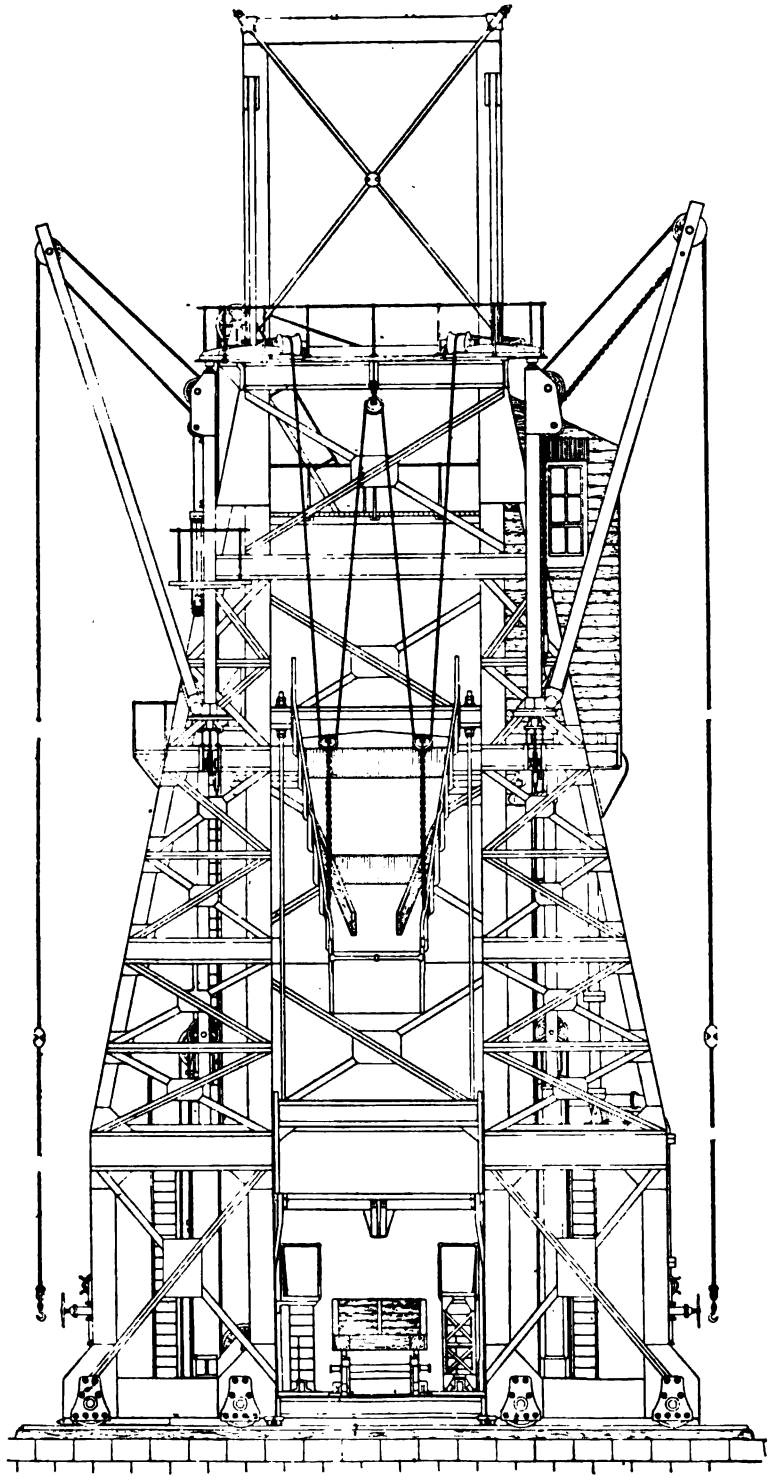


Fig. 17.—Hydraulic Coal Tip. (Front Elevation.)

one small, and one large, one on each side. The function of the smaller one is to partially balance the weight of the cradle. The four rams, 45 feet in length, press against a cross girder above the cradle that travels in vertical guides. The cradle is suspended from the cross girder with adjustable bolts, and the tipping cradle rests upon the main cradle, and is hinged on the end nearest the dock.

At the shore end of the cradle, wire ropes pass up on each side to near the top of the framing of the tip, thence over sheaves, whence they are carried by guide pulleys to the right-hand side of the tip, and down to and around the tipping ram and the cylinder, which is fitted with sheaves. The bight of the rope is carried from the sheaves of this cylinder over guide pulleys and up to the side of the main cradle, where it is passed over a sheave attached to the framing of the cradle.

The advantage of this rope arrangement is that as one rope only is used, any inequality in the stretch at either end is adjusted by the bight of the rope traversing over the sheave on the tip cradle. This rope, which takes the part of two ropes for the tipping cradle, is free to run round the sheaves of the tipping ram and cylinder as the main cradle lifts or lowers, carrying the tipping cradle with it. To tip the cradle, or

a wagon, water is admitted to the tipping cylinder. By thus forcing out the ram the rope is shortened and the cradle tipped. By releasing the water the tipping cradle returns to the main one. In the event of the tipping cradle being lifted very rapidly, cross girders fitted to the main cradle act as stops to prevent the wagon from being thrown off the tipping cradle.

The hinged shoot is lifted and lowered by means of the main cradle, upon which there is a pair of sliding dogs, which can be pushed out to engage in the shaft which carries the butt. It is held in position by means of chains, each attached to one end of the shoot shaft, and carried up to the top of the tip framing, thence over sheaves and back down alongside the middle frame of the tip; the chains are there secured by bolts in cleats.

The point of the shoot is moved by means of wire ropes that pass to the top of the tip and thence to a crab, which is driven by three-cylinder hydraulic engines, fitted with brakes for adjusting the point of the shoot. The shoots are pivoted, and capable of being radiated to right or left, 5 feet from the centre of the tip, so giving a range of 10 feet. As the walking pipes that supply the pressure water have a range of 15 feet, this makes 25 feet available for the movements of the shoots.

There are two jib cranes on each tip, of four, and eight tons power respectively, used for depositing coal from an *anti-breakage* box, and employed for preliminary deposition of coal. The object of the anti-breakage cranes and bucket is to partly fill the ship's hold, previous to the dumping from the shoot. The crane lowers coal in sufficient quantity to form a conical heap, and the coal afterwards shot in is much less liable to break than if thrown in on a flat bottom. The cranes are independent of the tip, so that they need not be used when the coal is not liable to fracture, or they can be utilised for handling general cargo when the tip is not in use.

All the movements of the tips are controlled from an elevated cabin, whence one man lifts or lowers the main crane, tips or returns the tipping cradle, controls the anti-breakage cranes, lifting, lowering, and swinging the anti-breakage boxes.

The cradle can be automatically stopped at any required height by setting a thimble on a vertical guide rod, a lever being attached to the latter, which actuates the valve of the pressure and return mains that control the movements of the cradle. Adjustment and securing of the thimble is made when the first wagon has been brought to the required height. Afterwards when the cradle rises, a pointer coming in contact with the thimble automatically shuts off the pressure, and the wagon stops. The attendant then tips the cradle. The reverse operation also takes place on opening the release valves.

The water supply is brought through walking pipes. It is returned through a 12-in. main. There are suitable accumulators.

The capacity of these tips may be judged from the following:—On one day the *s.s. Gatesyarth* arrived in Penarth dock at 8.10 on the morning tide. After bunkering at one tip, she commenced to take in her cargo at 9.15 A.M., and finished at 11.50 A.M., going out on the same tide with a cargo of 2,333 tons, taken in in 2 hrs. 35 min.

Cranes resembling this broad type are made, operated by electric motor, carried on a platform at the top of the staging.

There are many steam, hydraulic, and electric cranes which have a coal-tipping arrangement fitted to them as an adjunct. The truck is suspended from the snatch block; and a separate chain or rope, and lifting gear are fitted for tipping. Examples of these are given in Figs. 18-20, Plate II.

The bridge tramway plants for coal handling are differently designed. But in large installations they generally include the bridge proper, occupying the space between the towers, a cantilever extension over a storage building, and a hinged apron—the loading and unloading portion. Three or four of these comprise a plant. *See* **Bridge Crane**. In the Brownhoist system two standard sizes are embodied as follows:—

180 ft. span, with a cantilever extension beyond the back pier of 80 or 104 ft., and 34 ft. apron over the vessel. 192 ft. span with the same length of cantilever, and apron as above. The cantilevers are only fitted when necessary. The apron is an integral part of the design, being hinged so that it can be raised to

a vertical position when not in use, so leaving the dock side unobstructed until vessels are moored alongside, when it is lowered for service. The tracks run over on the apron.

Though the bridge piers are movable on tracks, only the front one is moved at the time of loading, being skewed to adjust the apron to the hatches of vessels without moving the back pier. One operator is sufficient for a plant of three or four bridges. Light loads and rapid handling are the features of these plants. A round trip can be made from a vessel's hold to the end of the cantilever and back in a minute, a distance of 600 ft. Another type to which the term *fast plant* is given, comprises a number of separate machines arranged in a row, spanning two or more railway tracks, with cantilevers reaching over other railway tracks, so that six or eight cars can be standing under each machine, loading between shifts.

Coal Washing.—Certain of the smaller lumps of coal, and all the small coal that is to be made into coke are washed, the former to increase their market value, by removing the foreign matter, the latter to produce better coke.

All coal-washing machines are built to take advantage of the difference in the specific gravities of the foreign matter, principally pyrites, and the coal. In all of them a stream of water plays a very important part, the lighter coal dust being carried in one direction by the stream of water, and the heavier dirt in the opposite direction by some part of the apparatus. There are several forms of apparatus for accomplishing this. In one the coal dust passes down an inclined trough, being propelled by a stream of water, while a series of scrapers fitting close to the bottom of the trough pass up it, worked by an endless chain, the scrapers collecting the dirt which falls to the bottom of the trough, and carrying it to a receptacle provided for it at the top, while the stream of water delivers the coal dust into another receptacle at the bottom. In another form there is a large iron tube revolved by rollers fixed on its outside, with a coarsely threaded screw formed on its inner surface. The water carries the coal dust out at the bottom of the tube, which is slightly inclined, while the dirt falls into the depressions formed by the screw thread, which forms an archimedean screw, and is carried to the top. In another an inverted truncated cone receives the coal to be washed at the top, while a stream of water is forced up into the cone from below, and the whole is kept in motion by revolving arms. The dirt passes downwards into a cylinder below, while the coal passes out at a slightly higher level. In another form the coal in process of washing is kept continually in motion by a piston which moves up and down in one chamber of the washer, a screen being fitted in the other, with the usual stream of water, the dirt being separated by falling quicker than the coal, the dust of the latter being carried off by the stream of water. The action of this form of washer is aided, for small coal, by the addition of a bed formed of small pieces of felspar, which acts as a sieve, separating the coal from the dirt, the dirt passing through it while the coal passes away above.

Coarse.—Has many applications; as a coarse feed applied to cutting tools, a coarse fibre of ductile metal, or grain of crystalline kinds. A coarse file has large teeth widely spaced. An emery wheel having large grains, a toothed wheel of large pitch, or copper in a particular stage of smelting, are termed coarse.

Cochran Boiler.—A well-tried and useful type of vertical multitubular boiler, Fig. 21. Its advantages over the ordinary vertical are an increase of heating surface, combined with accessibility of the tubes for cleaning; as both the smoke box, and what may be termed the combustion chamber, on the side opposite, have doors to open for cleaning, while the upper outside surfaces of the tubes are open to inspection from above. The absence of an uptake leaves room in the domed top for a man to get in, which is not possible in ordinary vertical boilers. A frequent cause of grooving in the furnace crown is also thus removed.

These boilers are made from 3 ft. diameter × 6 ft. 9 in. high, with 60 sq. ft. of heating surface; to 8 ft. 6 in. diameter × 17 ft. high, with 1,000 sq. ft. of heating surface. The usual working pressure is 100 lb.

Cock.—The principal kinds of cocks and valves are treated under their special headings.

Cod.—A mass of sand separated from the body of a mould; or a block of metal, as the slipper pieces in friction clutches.

Coefficient.—A number or factor which

bears a definite relationship to another. *See* **Coefficient of Friction.**

The modulus of elasticity is sometimes termed the coefficient of elasticity. Coefficients are largely used in electrical calculations in such terms as c. of alternators, c. of induction, c. of hysteresis, &c.

Coefficients enter into the calculations dealing with the design of vessels, *e.g.*, c. of fineness, c. of water-line, Admiralty c., c. of propulsion.

Coefficient in Algebra.—Is the multiplier of a quantity. In the expressions, $7a$, $3xy$, bc, xy, the coefficients are 7, 3, b, and x respectively, the first two being *numerical*, and the last two *literal* coefficients. On the other hand, the other terms, a, xy, c, and y, may also be considered as the coefficients respectively of 7, 3, b, and x, so that a coefficient may be regarded as a *co-factor*.

Coefficient of Friction.—The ratio between the perpendicular pressure, and the friction between two surfaces in contact. In the case of a body resting on a horizontal surface, the *perpendicular* pressure is equal to the weight of the body, but where the surface is inclined this is not the case, as a little consideration will show. The coefficient of friction is represented by the Greek letter μ, so that if F represents the amount of friction, and R the perpendicular pressure, $\frac{F}{R} = \mu$ and $F = R \times \mu$. The coefficients of friction between various substances are given in pocket-books, and by using them in this equation the force necessary to overcome friction may be estimated. If, for example, the coefficient be ·38 and the perpendicular pressure be 10 lb., then $F = 10 \times \cdot 38 = 3 \cdot 8$ lb. Thus a force of 3·8 lb. is necessary to overcome the frictional resistance to sliding.

A practical method of finding the coefficient

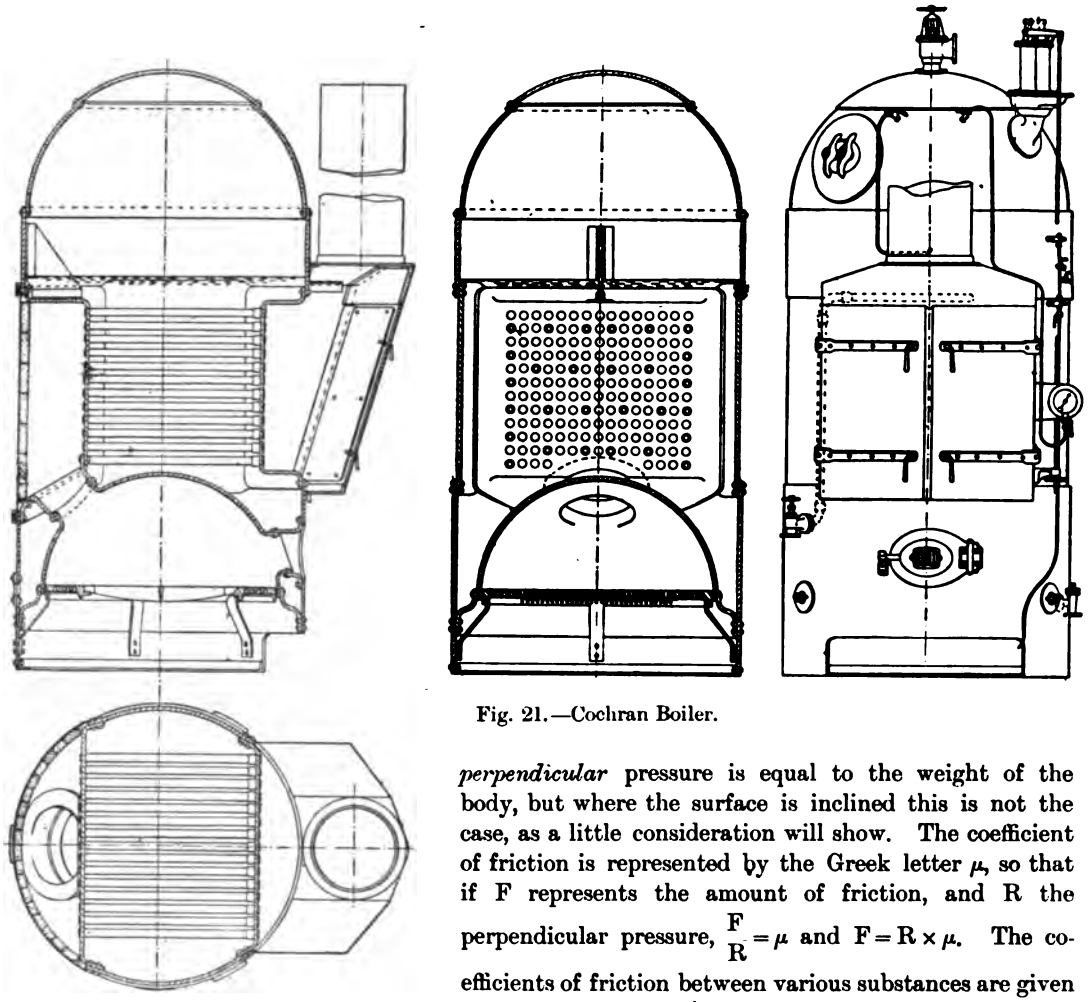


Fig. 21.—Cochran Boiler.

of friction between any two materials is shown in Fig. 22. AC represents a slab of one of the materials (in this case, cast iron), on which is a block of the other material (in this case, steel). AC is slowly raised until the block just begins to slide. The angle DAC is then the *angle of friction* or *angle of repose*, and the fraction obtained by placing the distance CD upon AD, *i.e.*, $\frac{3}{15}$ is the coefficient of friction between the two materials concerned. This ratio is the tangent of the angle DAC, so that instead of measuring AD horizontally, and CD vertically, the angle DAC may be measured, and its tangent found from a table. Generally coefficients are expressed in a decimal form.

Thus $\mu = \frac{3}{15} = \cdot 20$. For nearly all substances μ is less than unity.

The coefficient of friction may also be found experimentally by making AC horizontal, and

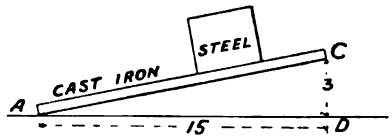


Fig. 22.—Coefficient of Friction.

fastening to the block a cord which runs parallel with AC over a pulley attached to the extremity A, and suspends a light scale pan. Weights are placed in the pan till the weight starts moving. Then if the weight of the steel = 40 lb., and 8 lb. in the pan are sufficient to start it moving, $\mu = \frac{8}{40} = \cdot 20$.

The coefficient thus obtained when the weight is on the point of moving is called the *static* coefficient, or coefficient of rest. Once B starts moving, the inclination of AC necessary to keep it moving becomes less. The coefficient obviously also decreases, and is then called the *kinetic* coefficient, or coefficient of motion. *See* **Friction.**

Cofferdam.—A wall built up in a stream, enclosing an area within which excavation, and pier erection, or other construction has to be done. The **Caisson** of steel has largely displaced the cofferdam of timber.

A cofferdam is formed generally by driving two rows of piles, an inner and an outer, separated by about 4 feet, between which the water is pumped out, and the space filled with clay puddle to form a water-tight wall round the area for excavation.

The timbers in the rows of piles and balks touch each other. They are connected at two places, at top and lower down with *wale* pieces. Against the latter another set of piles is driven, *sheet piles*, being formed of planks. Between the sheet piles, which face towards each other, the space of about 4 feet in width is puddled with clay in layers.

Cogging Rolls, or Blooming Rolls.—These are the first pair of rolls, between which a steel ingot is passed for reduction to sections suitable for finishing in other mills. The term blooming rolls is applied in America to the cogging rolls of the English steel works. These are the most powerful in a mill, and are a growth of the age of steel. Following the comparatively light mills of the old iron works came the cogging hammer, a steam hammer used for the reduction of ingots. With increase in size of ingots the hammer became ill able to produce homogeneous blooms and slabs. In 1884 the first cogging mill erected in Britain was put down at Blochairn.

The rolls of modern cogging mills are generally between 42 in. to 45 in. diameter, to deal with ingots of from 22 in. to 24 in. square. The continuous pressure exercised by the rolls, the reduced cost for labour, and the superiority of the product have had the result of displacing the hammer altogether for this particular kind of work.

There are two kinds of cogging mills, the two-high roll, or reversing; and three-high roll, non-reversing. Most mills are of the first-named group, but numbers of the second are in use in Germany, where the ingots are smaller than in Britain. With the growth in size of ingots the three-high type becomes less desirable. A two-high reversing mill requires reversing engines, but the objection to these by comparison with those which run continuously is lessened by the fact that they permit of instant variation of power by the control of the steam valve, which is not practicable with the continuously running engine.

The illustration, Fig. 23, is that of reversing cogging rolls in plan, from which the general

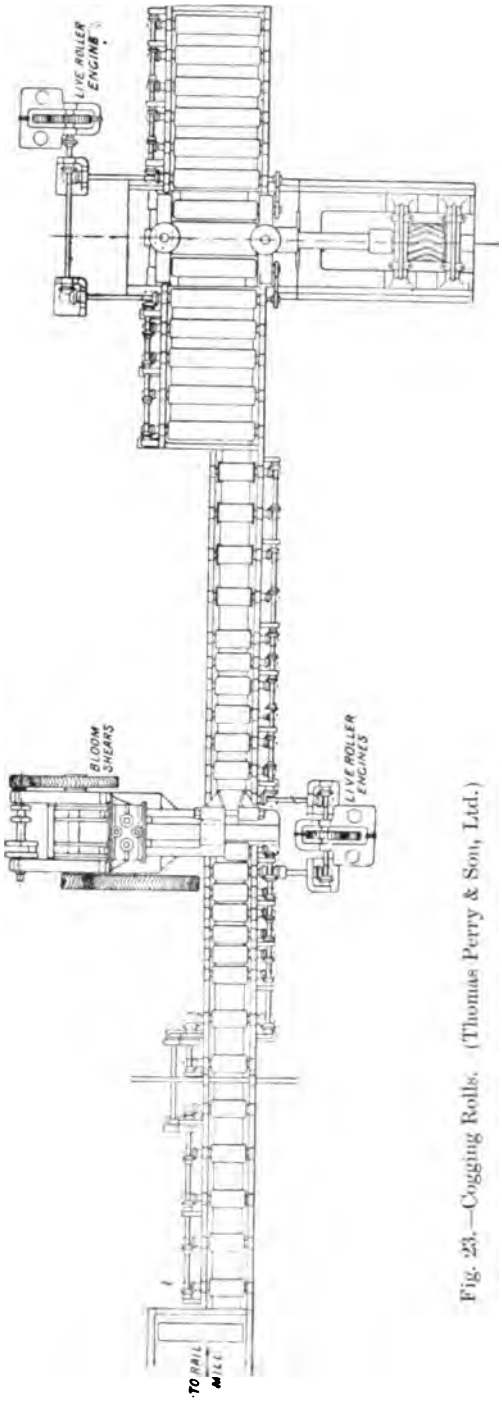
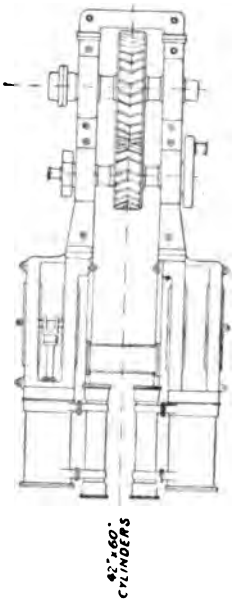


Fig. 23.—Cogging Rolls. (Thomas Perry & Son, Ltd.)

arrangement is apparent. The cogging rolls are seen in line with the crank shaft of the reversing engine. The live rollers are fed by two sets of engines, one set for the entering rolls, the other for the leaving rolls. The shears for cutting off the blooms to length are seen on the leaving side. The entire mill measures 114 feet in length.



Cogging Wheels, or **Gearing Wheels**.—Signifies the fitting of wooden teeth to **Mortice Wheels**, from the old term *cog* applied to a tooth of wood, as distinguished from iron teeth, to which "cog" is not now applied.

It is essential to good work that the wheel rim should be turned on face and edges before the cogs are inserted. The time occupied is saved in the latter work, besides ensuring the true running of the wheel.

The best wood for cogs is apple, following which come hornbeam, oak, beech, acacia, in about their due order of merit, though, of course, it is not altogether a question of timber absolutely, but one of quality of timber available. The writer has used them all, and found them all satisfactory, and has replaced teeth of each kind of wood taken from old wheels. One with beechwood teeth had been in use for forty years, and though worn badly, was perfectly sound.

Taking the wheel at the stage when it has been turned, the differences between spur and bevel wheels are substantially those due to the essential differences in these forms, described under their heads. We take the spurs first.

Fig. 24, A, shows sections through the rim and cog of a spur wheel, with one method of fastening shown. Two other methods are seen at B and C, the latter not being very desirable. The old pin fastening, A, is still the best. The cogs are sawn out with the grain running parallel with the axis of the shank and tooth, for in no other direction would strength be

secured. The shanks must be long enough to project about an inch within the rim, and the teeth must have allowances for turning after they are in place. The blocks are cut with a hand saw; or, if a circular saw is available, a block like Fig. 24. D, E, F, is used, to avoid the *shanking* of the sides by hand; the side of the block becoming a guide to lay next the saw. D shows the first operation, E the second. As the shanks have to be fitted singly, due to slight variations in the mortices, exact sawing is not necessary. The tops of the saw teeth coincide with the shoulders of the shanks. The height *a* in Fig. 24, E, corresponds with the top of the circular saw, compare with F.

removal, the shoulders are sawn exactly. Finally the shank is smeared with thick white lead paint, and driven down until the shoulder beds on the rim. The blows dealt must be dead and solid in character, and given right over the shank, instead of near the edges, which would flake off portions.

When all the teeth have been driven thus, they are secured with pins of iron rod, A, or clout nails with the heads cut off. Some men bore a hole right through the shank, and drive one long pin through. Where the shanks come next an arm the rim must be drilled for the insertion of the pins, G. If wedges are used, B, the shanks must be sawn or rebated before

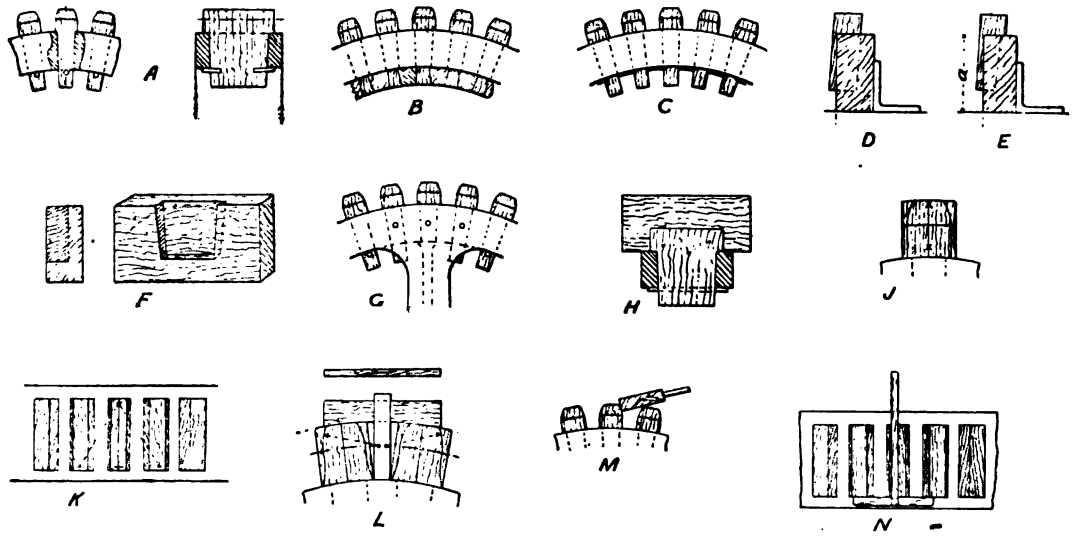


Fig. 24.—Cogging Spur Wheels.

The teeth are now fitted singly. If there are any roughnesses or arrises in the mortices, these must be removed with a coarse file, otherwise the shanks may appear to fit at first, but become easy a little farther in. Any superfluous wood is removed with a rebate plane, the dirty marks left on the wood from the mortice indicating the localities from which shavings have to be removed. The teeth are hammered in as far as they will go comfortably, and then removed and eased, and so on until they are got down to within about $\frac{1}{4}$ in. of the rim. Then a pair of compasses set to about $\frac{3}{8}$ in. is moved round the cog, one leg resting on the rim, and a line scribed all round the cog; by which line, after the cogs are driven in. The fastening at C is by strips of sheet iron with chamfered edges, driven in, in wedge fashion.

The cogs are turned up in the lathe on ends and tops, using a templet, H, and pitch lines ran round, the teeth pitched, and marked out, if they have to be marked by hand. These wheels are often cut by machine, in which case no marking out is required, but the wheel goes to the machine as soon as the teeth have been turned. When marked by hand the method of squaring up pitch lines on the ends and top of the teeth, is shown in Fig. 24, J, K. L shows the ends of teeth having their shapes marked by the aid of a templet, the blade of

which has centres for the compass points. The cogs are cut through with chisel and plane, M, as far down as the latter will reach, and checked with a small tee square, N. When

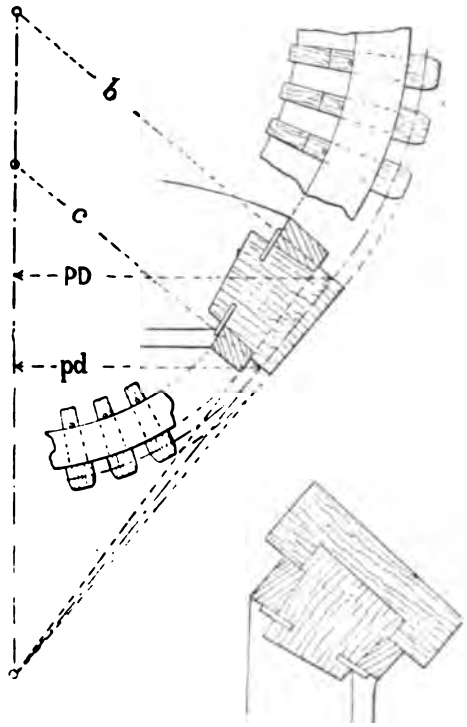


Fig. 25.—Cogging Bevel Wheels.

done they are saturated with boiled oil applied with a rag to harden their surfaces.

The cogs of bevel wheels have the relations of Fig. 25, the principle of construction of which is identical with Fig. 196, that illustrates the article **Bevel Gears** in Vol. II. The fitting of the cogs proceeds on exactly the same lines as in the spurs just described. They are turned by the aid of the templet shown in the lower figure, and the centre lines are set over by raising perpendiculars with compasses, as in Fig. 24, J. The teeth are worked similarly.

Cohesion is the force which holds together the particles composing a body. This attractive force is strong in solids, weak in liquids, and absent in gases. As it only acts at infinitesimal distances, portions of a fractured body cannot be united by placing them in contact. If the surface be very smooth, however, as in the case of plates of metal, or marble, and the two faces be pressed together, cohesion acts sufficiently strongly as to require some amount of force to separate the two slabs. The properties of malleability, ductility, elasticity, &c., present in metals are due to the cohesion of molecules. The relative degree to which cohesion between the molecules exists in various bodies is represented by their ultimate tensile or cohesive strength.

Different degrees of cohesion in liquids produce *viscous* liquids such as oils, and *mobile* liquids such as ether and alcohol.

The term *adhesion* is sometimes used to denote the attractive force between the molecules of different bodies, and also to indicate the action of glue, gum, paste, &c.

Coil Clutch.—A device, the object of which is to obtain the advantage of the common cone clutch without its drawbacks. These are the non-elasticity of the latter, its liability to seize, the need of end pressure to keep it engaged; and in some severe duty, as in fast running mechanism, the rapid wear of the conical surfaces. The coil clutch, Fig. 26, consists of two principal members, to one of which is attached a coil of steel enclosing the other member consisting of

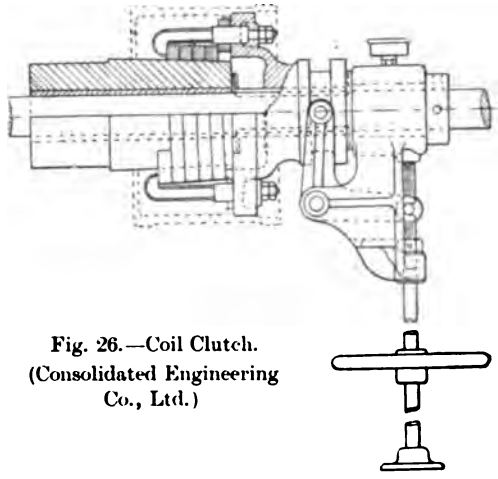


Fig. 26.—Coil Clutch. (Consolidated Engineering Co., Ltd.)

a hardened drum, which it is caused to grip in a manner analogous to a rope on a capstan.

In the more elastic form of clutch employed for high speeds the drum is made slightly conical, and the coil is pushed upon it until friction

causes the latter to contract. In the less elastic form employed for heavy duty at low speeds, the drum is cylindrical, and pressure is applied to the free end of the coil until friction induces a coiling action throughout the spiral.

When a mechanism has been perfected, new and varied applications of the same are continually suggesting themselves. The coil clutch is no exception. Besides the obvious and every-day utilities of clutch connections to shafting and machines, one of much importance has been added, that to the reversing of mill engines. The loss of power due to reversing rolls is great, though the energy stored in a flywheel is sufficient to enable an engine running continuously to do the work for which reversing engines of three times the power would be required. A case is cited in which a compound condensing engine running continuously with a flywheel of 50 tons weight, and indicating 800 HP. at from 55 to 60 revolutions per minute, was found capable of doing the same work for which reversing engines of 3,000 HP. had been found necessary. The mechanism is that of two coil clutches (taking the place of our old friend the cone clutch). Either one being thrown into action operates its own set of spur gears for driving or reversing. In some cases levers are used as the means of operation, but in big powers steam-starting gear is employed. Reversers as high as 1,500 and 2,000 HP. have been fitted.

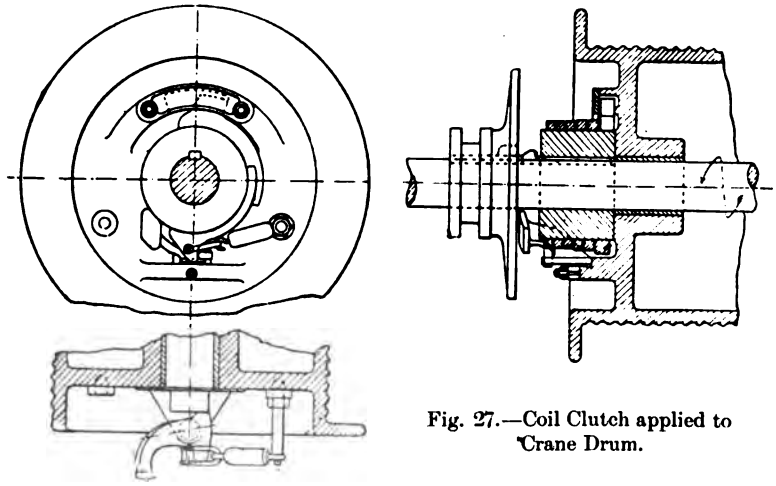


Fig. 27.—Coil Clutch applied to Crane Drum.

Another interesting application of the coil clutch is that to the reversing of the propeller shaft of a motor boat. It is simply the double cone and three bevel wheels again, but with the coils substituted for the rigid cones.

Another successful application of this clutch is being regularly made to the "free barrels," Fig. 27, of the cranes constructed by Messrs Stothert & Pitt, Ltd. The barrel runs freely on its shaft, and is put into and out of action by the closing and releasing of the clutch.

Coining Press. — A powerful type of stamping press, employed for impressing the faces of coins by means of dies. The movement is obtained by toggle levers actuated from a belt-driven shaft. The coins are fed into a shute, whence they drop on to the bottom die and receive the pressure of the top die. They are then automatically ejected. The work is severe, and pressures up to 400 tons are employed, so that a strong construction is essential. Two forms are seen in the photos, Figs. 28 and 29, Plate II., the first having a frame built up with pillar bolts, the second a solid arched casting. The dies used in these machines are produced by "striking" from an engraved die, also called a "hub" or matrix, which impresses its pattern on the comparatively soft metal of the working die. The forging of the latter is topped in the lathe to a cone angle of 120°, placed under the hub in a die-sinking press, of the fly type, and given a blow; it is then annealed, and turned off to a smaller diameter, another blow given, annealing and turning repeated, and the third blow given, when the impression should be sharp and complete. A little turning is then done to bring the die to proper shape, and it is hardened and polished. The production of coins varies from 60 to 100 per minute.

Before the stamping can be done, the discs



Fig. 15.—Hydraulic Coal Tips at Penarth.
(Fielding & Platt, Ltd.)



Fig. 18.—35-Ton Steam Coaling Crane.
(Cowans, Sheldon, & Co., Ltd.)



Fig. 19.—Hydraulic Coaling Crane Tipping into Vessel.
(Sir W. G. Armstrong, Whitworth, & Co., Ltd.)



Fig. 20.—25-Ton Hydraulic Coaling Crane.
(Cowans, Sheldon, & Co., Ltd.)



Fig. 28.—Coining Press.



Fig. 29.—Coining Press.

(James Watt & Co.)

To face page 28.

must be cut out, this being done in a blanking press of ordinary type, having a self-feeding mechanism for moving the strip metal along under the dies. The edges are also thickened up, on a separate machine, by means of a roller pressing on the periphery.

Coke.—There are two varieties of coke, the by-product of the gas-works' retorts, and the hard coke of the ovens prepared for furnace use. The first is only employed in the foundry for open fires, and for brass-melting furnaces, and not always for these; the second is used in cupolas and blast furnaces, hence termed furnace coke.

The higher priced qualities of coke are cheaper than the lower because they are more free from sulphur, which is the most undesirable element that can be present, as some of it is absorbed by the iron, producing a brittle material, and one which is liable to contain blow holes in the castings. Sulphur should not exceed 1 per cent. in samples. The presence of sulphur is most injurious when melting is done slowly, and when the heat is insufficient, since more of it then enters into union with the metal. A good coke contains about 93 or 94 per cent. of carbon, from 0·7 to 1·0 per cent. of sulphur, ash from 3 to 5 per cent., and free moisture something under 1 per cent.

Although some of the percentages seem small if viewed thus, yet when reckoned in lb. per ton, they show serious items. Thus, a ton of coke, with the composition: carbon, 95·77 per cent., sulphur, 0·71 per cent., ash, 3·40 per cent., moisture, 1·2 per cent., contains 2,145·24 lb. of carbon, 15·904 lb. of sulphur, 76 lb. of ash, and 2·6 lb. of moisture. As the carbon is the essential element, the coke which contains most carbon is to be selected preferably to one which has less. For even if its price is higher, its efficiency is greater.

Good coke is hard, heavy, uniformly lustrous, without black specks, and when broken it flakes off in needle-like crystals. Its density is necessary to enable it to withstand the pressure of the metal in the furnace. If it became crushed it would prevent free movement of the gases, and the essential reactions which result. It must be dry when purchased, and kept under cover. It should be free from dust and breeze. *See* **Cupola.**

Coke Basket.—A moulder's hand-basket used for carrying coke for the small fires employed for drying moulds.

Coke Bed.—A **Cinder Bed.**

Coke Grab.—*See* **Grabs.**

Coke Nest.—*See* **Birds' Nesting.**

Coke Ovens.—The ovens in which coal is converted into coke by a process of dry distillation. These have undergone great changes during the past twenty years, chiefly from non-by-product to by-product types.

The Beehive Oven.—The oldest form, and one which is still used for making about half the furnace coke produced in Great Britain is the *Beehive*, so named from its external similarity to the dome shape of the hive. It is of circular, or of square outline, ranging from 12 ft. to 15 ft. in diameter, and from 8 ft. to 10 ft. in height, and is built in blocks with dividing walls. The coal is charged through a door in front, placed in a heap, and coked by heat reflected from the roof chiefly, the furnace being therefore of the reverberatory type. The coking proceeds downwards, and the heat is obtained by the combustion of volatile matter in the coal, by the air admitted above the fuel. The process takes about forty-eight hours, the heat developed does not exceed about 900° Fahr., and therefore only coal rich in volatile constituents, or from 25 per cent. to 30 per cent. can be used. From 60 per cent. to 65 per cent. of coke is produced on an average. The waste gases are utilised for steam boilers, but there are no by-products, all the elements that are not retained in the coke passing away with the waste gases.

Numerous attempts have been made to improve the Beehive with the object of recovering the by-product, but they now have little interest beyond that of a chapter in the evolution of present types. It was formerly believed that the increased percentage of coke obtained in the product ovens must be accompanied by a sacrifice of some calorific value of the coke. That belief is no longer held. Beehive coke has also more lustre than by-product coke, but that is due to the fact that the first is quenched inside the oven, and the second outside. The waste of Beehive coke is due to the fact that some internal combustion of the coal takes

place, due to the admission of air to the coking chamber.

With regard to the old standing prejudice against by-product coke, which, of course, must not be confounded with the by-produce of the gas works, Mr C. Lowthian Bell disposed of that by a series of experiments. He took the by-product coke from Huessener ovens, and compared it with Beehive coke. In regard to consumption, a furnace used 22·73 cwt. of best Beehive coke per ton of pig, another using Huessener by-product coke required but 21·61 cwt. per ton of pig. Subjected to tests for hardness the by-product proved the harder.

By-product Ovens.—The salient features of the new types are the recovery of by-products, the exclusion of the air from the coking chambers, the substitution of long, narrow, and high chambers for the heaps of the Beehive, the use of regenerators, or other devices for heating the air. To this product the general term *retort coke* is given, in opposition to *Beehive coke*, and the ovens are often termed retorts. A feature of these is, that they can be used with or without recovery of by-products. An advantage of tall ovens is that the weight of the coal during the process of coking tends to increase the cohesive power of the coke. Coal is often compressed before introduction, but if so, height still increases the compression. Two systems are in rivalry in the modern ovens, the horizontal and the vertical positions of the air-heating flues, for each of which a high temperature, and short period of coking are claimed.

Appolt Ovens.—Appolt ovens are a rather old type, used abroad, and combining both vertical and horizontal flues. The coking chambers are very tall, 13 ft. in height, and tapering from about 4 ft. 8 in. to 3 ft. 8 in., by 1 ft. 6 in. to 13 in. Charging is effected at the top, vertical and horizontal flues are connected, and the dampers are placed in the former.

The Coppée Oven.—This is one of that large group which has vertical side flues. The ovens are worked in duplicate, two ovens being regulated from galleries at each end.

From the combustion chamber the flames ascend through vertical flues to a flue on top of the side wall. Thence they descend by three vertical flues, which lead into the flue under the floor of the oven, so that the oven is heated on both sides along its entire length before the heat leaves it on its way to the main collecting flues, and to the chimney and boilers. When these ovens are working as by-product ovens the heat is introduced at the bottom part, so that overheating of the top part shall not occur where the gas is taken off to go to the by-product plant; hence the temperature being low, the light oils contained in the gas escaping from the ovens are not decomposed.

The oven works with a pressure of about $\frac{2}{10}$ mm. at the top of the side walls, and with nothing at the bottom, so that it is only below the floor, where no gas can be drawn from the oven, that the draught commences, hence leakage is hardly possible.

Simon-Carves Oven.—This is of the horizontal flue type. The heat transmitted through the oven walls is obtained by burning a portion of the gases distilled from the coal after they have been deprived of the ammonia, tar, and benzol. The gases circulate in brick-work flues underneath, and at the sides of the ovens. Great stress is laid on the solidity of construction of these ovens. Also, the air for the combustion of the gases passes first into the galleries of the foundations, where it is warmed on its way to a flue in which it is heated to about 550° Fahr. The air-supply is capable of regulation at stages in its course through the flues. The ovens are heated in two zones, a lower and a higher; the first heats the sole and the lower part of the side walls, the second all the upper part of the side walls, and each is in duplicate on each side of the ovens. The dimensions of the ovens are usually 32 ft. 9 in. long, by 8 ft. 2 in. high, by from 20 in. to 22 in. wide. Each oven therefore is built long, narrow, and high, proportions which are favourable to economy. Several are built side by side with thick partition walls containing heating flues. Flues are formed under the floors, and the gas travels through various passages connected with three horizontal flues independent of each other. The advantage is a shorter length for each flue, and reduction of draught necessary, with lessening

of risk of leakage. Also, each zone being independent of the others, allows of independent alteration of the temperature in either zone. The ovens are charged from above.

Otto-Hilgenstock.—This is a vertical flue oven, Fig. 30, fired at the bottom with Bunsen burners, and the system is thus based on the principle of the widest distribution of gas through the shortest course. As the gases have to travel a very short distance, the chimney draught is reduced to a minimum, and risks of leakage are lessened. The gases given off from the coal in the oven chamber A pass through the opening B into the gas main C on top of the ovens, whence they are drawn into the gas coolers, and other by-product recovery apparatus by means of steam jet gas exhausters. The gas which remains after the by-products have been abstracted returns through the main pipe D, which supplies a battery of ovens. Small pipes branch off from D into the arches which support the ovens, and from these other branches come off at right angles, terminating in nozzles of Bunsen burners inserted in the heating flues of the chambers. These chambers draw in sufficient air for combustion, which air is heated on its way from the arches by the heat of the waste gases flowing through the sole flue.

The flame ignites at the level of the coking chamber, and rises vertically through the heating flues G to the horizontal top flue H. Thence the burnt gases divide and come down through vertical flues J under the sole flue, which is the bottom of the oven, and there reheat the air and gas on their way to the combustion chamber as just stated. They are lastly drawn through the opening M to the main waste gas collector N, to a boiler plant for steam raising.

The by-product recovery plant receives the gases from the collecting main C. They are passed through a serpentine cooler, and water coolers, by which their temperature is lowered to about 20° C. They are then freed from ammonia or benzole. Fig. 31 illustrates this plant.

The following figures give a concise view of the value of a by-product plant. Sixty Otto-Hilgenstock ovens, coking coal with 25 per cent. of volatile matter, will coke 400 tons of coal in twenty-four hours. This will produce 480 tons of steam at a pressure of from 100 to 120 lb. One-sixth of this is used by the by-product plant, leaving 400 tons of steam available for other purposes. Or, 400 tons of coal will yield 4,200,000 cubic feet of gas, leaving 1,200,000 cubic feet available for gas engines, after allowing the other two-thirds for heating the ovens.

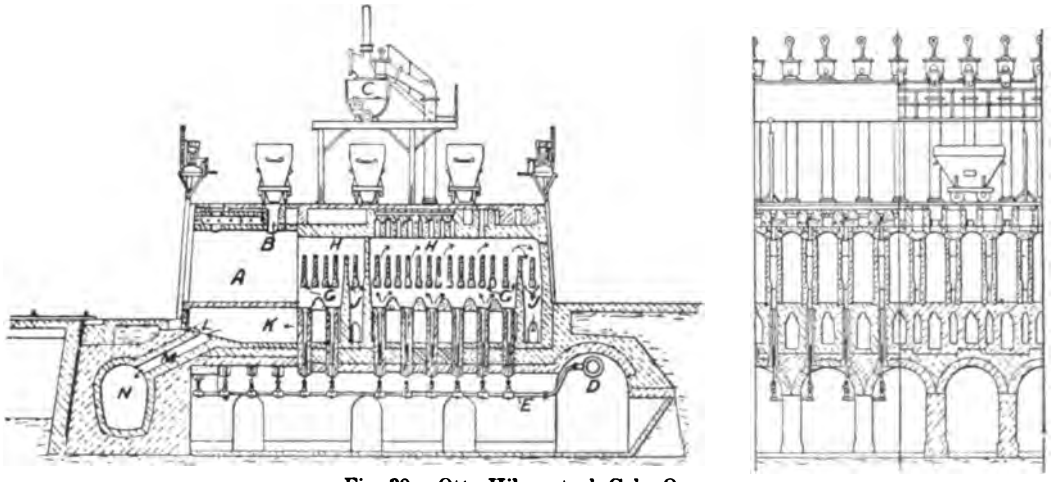


Fig. 30.—Otto-Hilgenstock Coke Oven.

The Huessener Oven.—This is a horizontal flued oven with horizontal heating flues, and the gas is introduced in twelve places, so distributing the heat equally. There is a longitudinal division wall under the middle of the oven sole which divides the gas for each oven into two

portions, each travelling through an independent set of flues on each side of the oven, which permits of independent regulation of the temperature. The usual dimensions of this oven are: length 33 ft., height to spring of arch 6 ft. 7 in., mean width 1 ft. 8 in. Each oven holds 7·66 tons of uncompressed coal, with about 10 per cent. of water, equal to 6·9 tons of dry coal. The time for coking depends on the kind of coal and its condition. Washed Durham coal with 30 per cent. volatile matter and 10 per cent. of water takes thirty-two hours to coke, dry coal only from twenty-six to twenty-seven hours. The yield of good blast furnace coke is 72 per cent., and of breeze about 2·5 per cent.

The Semet-Solvay Oven.—This is a horizontal flued type, without preheating in regenerators, but partition walls and the brick-work over the flues are made very thick to serve as a storage of heat. The horizontal flues, three in number, are not built into the chamber walls, but form a lining of fire-bricks easily replaced in any one flue without disturbing the work of the others. The gas passes off to the by-product recovery plant, and afterwards returns to the heating flues, and the portions not consumed can be further used for heating boilers. The dimensions of the oven are:—Length 30 ft. to 35 ft., height 5 ft. 8 in. to 6 ft., width from 13 in. to 20 in.

The Bauer Oven.—This is a vertical flued oven in which heated gas and air are introduced into each vertical flue separately. This ensures reduced velocity of the gas and chimney draught, and a less difference of pressure between that in the flues and the coking chamber. The combustion chamber is in the upper flue, whence the gases from the vertical flues are collected in a sole flue under the coking oven, and are conducted away to the chimney. The Bauer ovens are from 30 ft. to 40 ft. long, their height from 6 ft. to 7 ft. to the crown of arch, and their width tapers slightly from 20 in. at the front to 19 in. at the hinder end. The average

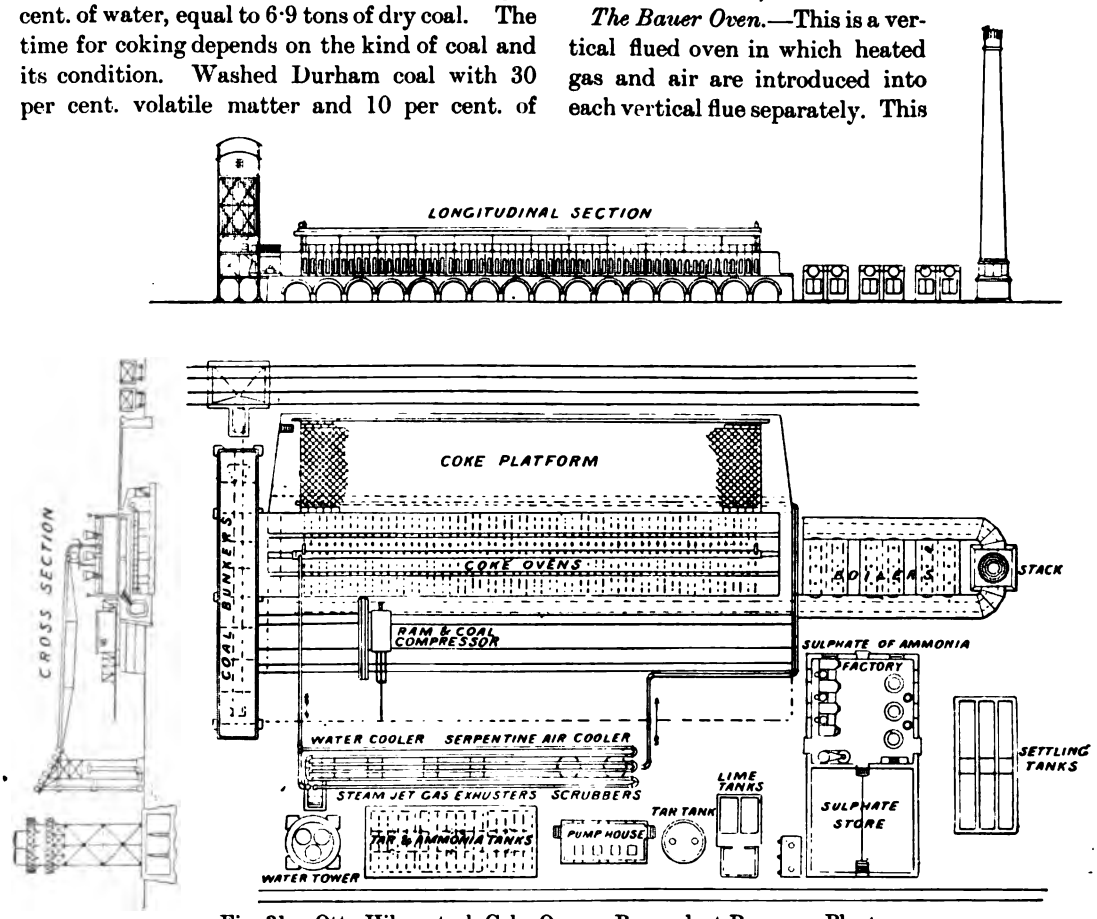


Fig. 31.—Otto-Hilgenstock Coke Oven. By-product Recovery Plant.

capacity is about 10 tons. The yield is about 73 per cent.

Good ovens have been designed besides these, as the Brunck, Koppers, Collins, Poetter, &c., but we cannot give space to them.

By-products.—Tar and ammonia are received from the coal gases, the ammonia is obtained as water of ammonia, which, being heated, gives off ammonia vapours, and being led into sulphuric acid yields the fertiliser sulphate of ammonia. Tar obtained by condensing the gases is distilled, and these on being again condensed produce crude naphtha, benzole, light oils, creosote oils, colour oils, and aniline dyes, and pitch. Mr Mallmann has estimated that if by-product coke ovens were employed universally through the United Kingdom, the net profits to the iron and steel industry annually would be £3,000,000, basing his estimate on the fact that 50,000,000 tons of coal are coked annually for metallurgical purposes, and on the present price of sulphate of ammonia at £12 a ton, and of coal tar at £1. 10s. a ton.

Cold.—Prefixed to many terms; as cold blast; cold chisel,—the chipping chisel; cold saw, or cold-iron saw for cutting iron cold; cold riveting,—without heat, adopted in very small rivets; cold rolling,—applied to thin sheets of metal, and alloy, which hardens and would crack them but for frequent annealing; cold sand, as distinguished from foundry sand which has been recently cast into, and which sticks to a pattern. Cold sett,—a smith's long handled chisel used for nicking cold iron and steel, and having a more obtuse bevel than the hot sett. Cold shortness, denoting iron and steel which fractures readily when cold; and cold shut,—a line of incipient cleavage in a casting, due to two masses of metal meeting in a mould, and not having sufficient heat and fluidity to amalgamate perfectly. Cold tests,—bending tests on specimen pieces of iron and steel; cold-water pumps, as distinguished from those used for hot liquids; cold-water tests, applied under pressure to steam boilers.

Cold-Blast Iron.—Pig iron smelted in furnaces supplied with blast that has not been preheated.

It has almost always been assumed that the cold-blast pig is better for castings than the hot-blast. But clear demonstration is lacking. The experiments by Sir William Fairbairn were not conclusive either way. The only thing that is certain is that the hot-blast product is rather more silicious than the other. Sir I. Lowthian Bell has argued forcibly against the superiority of cold blast, and concludes his contention thus: —"Of course it is impossible to lay aside the experience of impartial consumers of pig iron, who, paying a high price for an article for special purposes, must have satisfied themselves that it is worth the money. No doubt the iron they prefer is good, and it is cold blast, but is it good because it is cold blast? This is precisely the question which has not perhaps received sufficient attention."

Cold Saw, Cold Sawing Machine.—This is employed very extensively for cutting off bars, rails, sections of all kinds, plates, tubes, and also for taking out lumps of metal, alternatively to slotting, such as from crank webs, connecting rod forks, &c. The saw blades have the teeth either in the solid, or as inserted tools. Fig. 32 gives views of a machine by Isaac Hill & Son, comprising a short bed A, to which the work is bolted or clamped, and a longer slide bed B; on the latter a carriage travels, carrying the saw D and its bearings. The driving is effected, first by the fast and loose pulleys E, through the train of spur gears to the splined shaft F. A sliding gear on the latter drives to the spur G, on the same shaft as the bevel pinion H, rotating the bevel wheel J, which is mounted on the saw spindle. The carriage movement is derived first from the shaft F, which is prolonged to carry a three-stepped cone K, belted to a companion L. The latter is connected through bevel and worm gear to the screw M, driving this when the claw clutch N is thrown in by the handle O. A quick return motion is obtained by the spur gears, which revolve the screw rapidly when N is slid into gear with the spur on the left. This reversal is not effected automatically. The dogs, which are struck by the slide C, throw the clutch out of gear only, and it has to be put into gear by hand for either the quick return, or the feed traverse. The tappet motion is only to prevent overrunning in either direction.

Variations upon this design are made to suit work of special character. The type of saw used is the flush-side, a detail of which is seen

at the right-hand bottom corner of Fig. 32. The disc is bolted to the spindle end through an intermediary piece with countersunk bolts, which being flush with the saw face, allow of sawing being done close to a surface, a valuable feature in such operations as cutting off runners or gates from castings, &c. These blades are made up to 42 inches diameter, and up to 8 feet and more with inserted teeth.

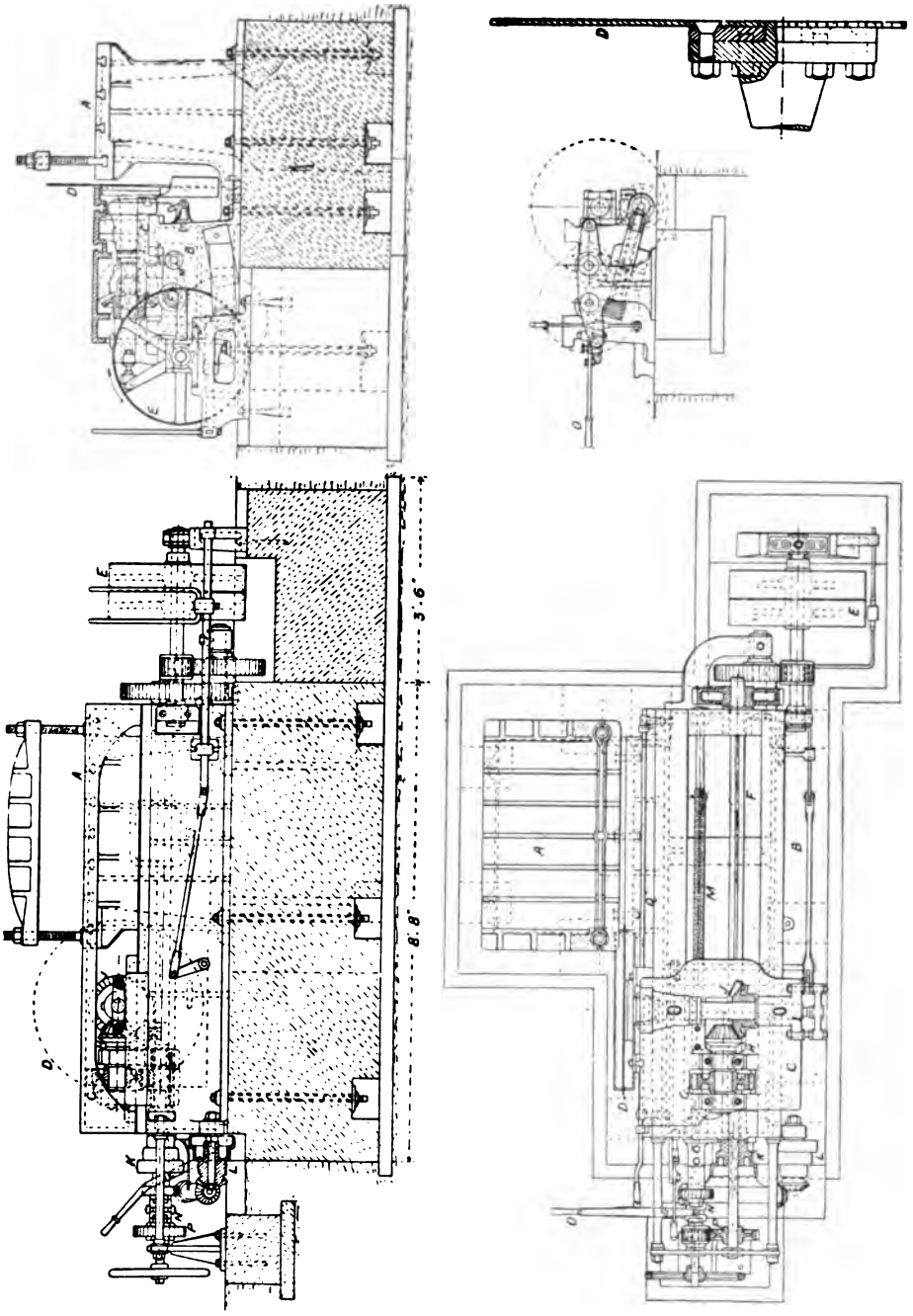


Fig. 32.—Cold Sawing Machine.

Cold sawing machines of this design can be

easily converted into ending or facing machines by substituting a milling cutter for the saw, the other arrangements remaining the same.

Another type of cold saw is the "lever," in which the blade runs with its shaft in a pivoted frame, driving being done by bevel and worm gears. The saw is lifted up, or fed downwards by a long lever projecting from the frame. A weight is often hung on this lever to give a self-acting feed.

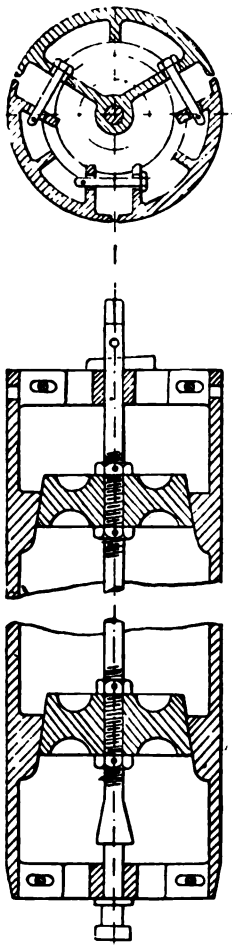


Fig. 33.—Collapsible Core Bar.

The saw runs above a slotted table, to which the work is bolted, any length being accommodated thereon.

Collapsible Core Bar.—A bar made in a few designs which have the one feature in common, of instant collapse. The body of the bar is made in segments, Fig. 33, which fall in towards each other on the knocking back of the cotter in the central shaft carrying the cones, which then drop. Lugs on the ends of the segments have slot holes to permit of the inward movement of the segments. The reason why these bars are used instead of solid ones is an economical one. The hay bands, or straw ropes wound on the rigid bars are costly, and though suited for jobbing work are not used so much in regular pipe founding. The loam or sand is swept directly on the collapsible bar, with a little tow wound round to retain it. The trouble of loosening and knocking out the solid core bars is also considerable, and this is practically *nil* when the bar is made to collapse inwards.

Collar.—Generally signifies an annular enlargement on a shaft, the object of which is to prevent endlong movement of the shaft. Collar bearings are thrust bearings. A collar gauge is a ring gauge. Collar tools are smith's top and bottom tools for finishing corresponding portions of forgings. Collaring is said to occur when a rolled section clings to and bends round the rolls instead of passing straight on.

Collecting Rings.—Means for collecting electric currents by a revolving piece of work from a fixed pivot or ring, commonly applied to electric cranes, &c. The usual form consists of two or more metallic rings properly insulated and secured to the fixed part of the machine; suitable brushes are arranged upon the revolving portion, and are fitted with springs so as to make definite contact with the ring; the brushes may be of carbon or of gun-metal.

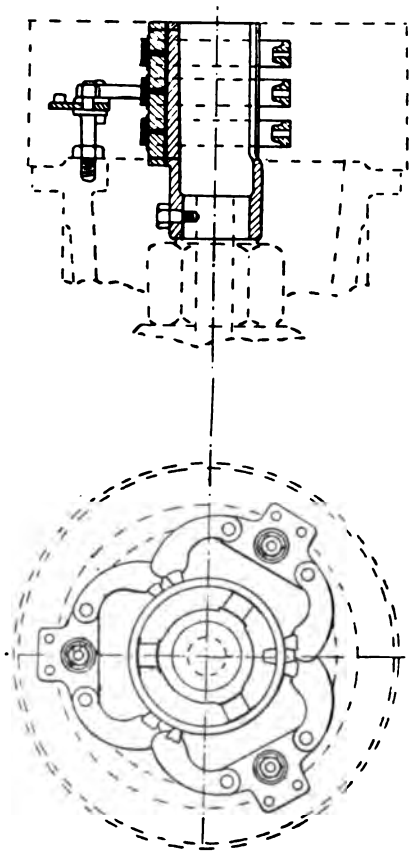


Fig. 34.—Collecting Rings.

The rings and collectors may be arranged in either the horizontal or vertical plane.

Figs. 34 and 35 show collecting rings by the Electrical Co., Ltd. In the first example the brush holders are fixed upright, in the second they are fixed sideways. In Fig. 35 the apparatus consists of a cast-iron tube with insulating and contact rings, brush holders, and cable lugs. A standard crane contact for slewing cranes cannot be designed because of

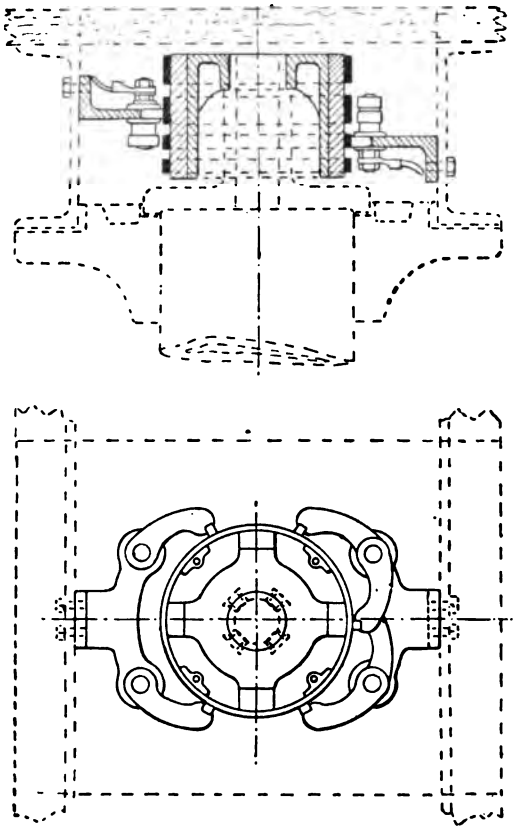


Fig. 35.—Collecting Rings.

the differences in crane types, so that these figures are illustrative of typical devices.

Collectors.—Appliances for collecting electric current from bare wires or metallic conductors; a trolley pole or a conduit plough on a tramcar, are examples. They have, however, their distinctive names. The term collector is usually applied to such details when they exist in simpler form, as upon overhead travellers, wagon and loco-traversers, Goliath cranes, &c. When they are fitted to such machines they usually consist of a short projecting arm, having a small pulley arranged to make contact with the wire; in some cases a solid non-revolving head is fitted instead of a pulley.

Collet.—This term is applied to various rings or bushes which serve as holders or adapters used for the gripping either of work, or portions of mechanism. A common example is that of the separate spring bushes inserted in the chuck of a capstan lathe or automatic screw machine, to hold the false jaws of varying diameters. These collets are either of the "push-out" or the "draw-in" type. Collets are also employed in die-stocks to grip the interchangeable dies, and to adjust them for size. The object is to provide a series of holders which are of uniform outside diameter to fit the stock, and yet have a different die in each. The setting screws in each collet permit of minute alterations being effected in the sizes screwed, and compensate for wear.

Milling cutters and drills need collets where shanks of varying diameters have to be held in a single spindle hole. Close accuracy is necessary in all collets which have to rotate, otherwise eccentric movement of the work would result; grinding therefore provides the best means of finishing, especially as hardening is usually done to ensure durability.

Column Making.—*Patterns.*—Patterns for columns are seldom turned from solid stuff, and only when of small diameter, say of 4 inches and under. It is better not to joint these small patterns down the centre, because they are liable to warp and open out in the joint, unless they are permanently fastened to a joint-board. Solid patterns can be moulded in a recessed joint-board, made specially for its own size of pattern. If this is not done, then the joint must be worked by hand at each time of moulding, using a strickle to get the centre, as is often done in jobbing shops. In such shops, castings are asked for of all lengths from a single pattern column, and as flanges have to be shifted, and flanges of different sizes and shapes substituted, this interferes very much with the use of joint-boards.

The larger column patterns are jointed and constructed by **Lagging**, and these retain their shapes very well. Less alteration can be

made in these than in plain columns destitute of mouldings.

Column mouldings being built in as integral parts interfere with much alteration being effected in length. These patterns, therefore, may be mounted permanently on bottom boards, one-half on opposite sides of the same board, or the ordinary board may be used to lay one-half of the pattern on.

Pattern columns are held during turning by **Centre Plates** of good size. The fork or prong centre may be used as in other turned work, but it is better for heavy columns to use the point centre at both ends, and to employ a driver, either to encircle the centre; or, which is preferable in this instance, to use one inserted in a small face plate, driving against a screw or stout nail driven into the end of the pattern, so rotating the work at a larger radius than the first named would do. The driving stud and the nail or screw in the pattern end should be tied together. Two drivers may be used to diminish torsional stress, as the turning of wood patterns of large diameter puts considerable strain on the parts.

Care must be observed to have the chucking plates on the exact centre joint of the work, for if otherwise, one portion of the pattern will be larger than the other, and this may, in some cases, lead to inaccuracies later, when flanges and other parts have to be fitted. A few dogs or staples should be driven in along the joint of the pattern to prevent it from springing apart, which it is certain to do unless secured in this way. The positions of these dogs are changed from time to time as the turning proceeds.

Before turning any portion to finished dimensions it is well to rough the pattern down all over with the gouge, and so expose the grain to the air. When this is done, look to the end plates, and see if the screws or nails have become loosened at all. If so, tighten these up, or insert larger ones.

If the column is a straight one, whether parallel or tapered, the shaft is now turned to correct dimensions at each end. Then a flat is planed from one turned end to the other along the shaft, using a straightedge to ensure its truth by. This flat is well chalked over, or painted with red lead in oil, so that it will remain a visible guide to the rest of the turning, without having to stop the lathe frequently to test the diameter at every section with calipers or with straightedge. During the turning, the chalk or colouring matter on the flat will be apparent until it is nearly obliterated, and when that stage is reached the work will have to be stopped, note taken of the progress of the turning, and the remainder done cautiously. But no stoppage need take place during the roughing down of the shaft, excepting for the purpose of changing the locations of the dogs. When taking the finishing cuts it is well to indicate the positions where material has to be removed by chalking the tool rest at these positions. The straightedge may also be brought into service.

When a column has entasis, instead of planing by a straightedge, the planing may be done to a templet having its edge cut to the curvature of the entasis. Or the shaft may be turned down to size at the ends, at the middle, and at two intermediate parts, and a flat be planed to connect these with a suitable curvature, the eye being the judge.

Only in the case of a column which is large in diameter relatively to length can the turning be done without support from a steady. The central portions will wabble, and the tool chatter and leave striations on the work. There is always a steady or two kept in pattern shops for the support of such work, requiring only the renewal of the actual movable blocks which encircle the pattern.

In Vol. II., Fig. 42, E, p. 41, one of these steadies is shown. The construction is obvious. Before fixing it, the column is turned about the centre down to its finished dimensions, or say within $\frac{1}{32}$nd of finished dimensions, to permit of the slight reduction in size which occurs by reason of the friction of the steady. Light cuts should be taken in order not to spring the work much, being as yet unsupported. When the column is held in the steady it must be lubricated continuously, or it will become charred by the heat generated. A mixture of soft soap, blacklead, and oil forms the best lubricant.

The mouldings may be either turned in their places on a column, or separately, depending on conditions. If they are glued on the lagging

to form integral portions of it, then, of course, they must be turned up in place. But if they are made as separate portions, plank-way of the grain, or lagged up separately, then they may be turned on the column, or separately on the face plate. The best way, in the writer's opinion, is to bore them out on the face plate, or else cut their holes out with a paring gouge to fit the shouldered portion turned for their reception on the column, and then attaching them to the latter, turn them up in place. They can be screwed firmly to the column, inserting the screws from the inside of the joint.

If bolt holes are cast in column flanges they can be located by pocket prints, or put in the mould with a stopping-off piece.

Moulding Columns.—Columns are cast upon their sides, and moulded generally by turning over in green sand, and are poured at ends or edges. The numerous variations in the shapes and proportions of columns involve differences in details.

The work of column moulding is identical with that of cylindrical articles generally, cast horizontally. The special difficulties which arise and the precautions to be observed are the following :—

The longer a column, the more risk is there of the core being lifted by the liquid pressure. Especial care must therefore be taken to sweep the core up on a stiff bar that will not spring easily, with risk of the air finding its way into the interior of the core. Also ample chapleting is essential in order to secure the core centrally. If a column core shifts, and the metal becomes much thinner in the top than the bottom, the column will not come out straight, but hollow on the thin side.

Another precaution relates to the mouldings on columns, and the matching of the cores therewith. The more closely the outline of the core follows that of the mould, the more sound is the casting likely to be, because great discrepancies in thickness of metal tend to produce draws. It is not, therefore, only to economise metal that the core follows the contour of mouldings approximately. Evils of the same kind will follow if the core is not set carefully in the longitudinal direction.

The cleanliness of the skin on a column depends on several things. The mould must, of course, be well vented. The metal must be thoroughly melted, clean and hot, and skimmed, and to give any dirt a chance to escape, two risers at least should be provided at the highest points, namely on the end flanges. The pouring basins should be filled to the brim before any metal is allowed to flow into the mould.

Columns are best poured from both ends at once, the runners coming in horizontally at the sides of the core between it and the mould. In thick columns this is sufficient, but in those that are long and thin it is better also to bring a third set of runners in at one side midway between the ends, arranged as a spray.

Columns. — Compression members whose ratio of breadth to length determines that they would fail by bending rather than by simple crushing. With a ratio of 4 or 5 to 1, it is safe to assume that a member is a true strut, and would fail by crushing. Above that proportion it is generally classed as a true column and would bend before failure; it must therefore be calculated to some extent as a beam, *i.e.*, its "moment of inertia" enters into the operation.

Columns may be divided into three classes, viz.: those having both ends fixed; those having one end fixed, the other end being rounded; and columns having both ends rounded. The common formulæ in use for calculating the strength of columns are those due to Gordon, and which are based upon the experiments of Hodgkinson; they are as follows :—

Columns with both ends fixed—

$$\text{Breaking load in tons} = \frac{A f}{1 + C \frac{l^2}{r^2}}$$

Columns with one end fixed, and one end rounded—

$$\text{Breaking load in tons} = \frac{A f}{1 + 1{\cdot}8\ C \frac{l^2}{r^2}}$$

Columns with both ends rounded—

$$\text{Breaking load in tons} = \frac{A f}{1 + 4\ C \frac{l^2}{r^2}}$$

where A = area of cross section in inches.
f = ultimate compressive strength of material in tons per square inch.
r = least radius of gyration in inches.
l = length of column in inches.
C = a constant depending upon the material.

The radius of gyration of a section is found by dividing its "moment of inertia" by the area of its cross section, and extracting the square root of the quotient.

The constant C varies with the material under consideration, and may be taken as follows:—

Cast iron $= \frac{1}{6400}$.
Wrought iron $= \frac{1}{36000}$ to $\frac{1}{40000}$.
Mild steel $= \frac{1}{32000}$.
Timber $= \frac{1}{3000}$.

Combination.—A term of wide application, signifying the union of two or more designs in one article. A combination caliper is one that combines legs for internal and external measurements; a combination chuck is one that has both concentric and independent movements of the jaws. A combination gauge has provision for external and internal measurements. Combination machines are numerous; as milling and drilling, or milling and planing, or drilling and tapping, and others the object in which is either to avoid re-setting of work in different machines, or to supply shops with general tools, rather than a number of specialised ones.

Combination Bevel.—A type which has two parallel blades, connected by a slotted link, which holds by bolts in grooves or slots in each blade. This permits of many useful settings of the two blades in relation to each other.

Combination Chuck.—It is often convenient to have both concentric or universal and independent movements of chuck jaws, and this need is met by the combination chucks, which occur in several varieties. Having both independent and simultaneous motions, an eccentric, for example, may be held with the jaws set out of centre, and then they can be moved simultaneously to loosen or rechuck the same, or a number of similar eccentrics. This, with other allied forms, will be treated under **Lathe Chucks.**

Combination Dies.—*See* **Drawing Dies.**

Combination Square.—*See* **Square.**

Combined Carbon.—*See* **Cast Iron.**

Comb Tools.—*See* **Chaser.**

Combustion (Lat. *comburo*, to burn or consume).—Combustion means the chemical combination of substances accompanied by the evolution of heat and light. In most cases, especially where the purpose of combustion is to produce light or heat (as in the burning of a candle or coal), the oxygen of the air is the supporter of combustion, combining with the constituents to form new compounds—with carbon to form carbon dioxide, CO_2, and hydrogen to form water, H_2O. Oxygen is, however, not always necessary to support combustion; copper burns in sulphur vapour, and chlorine burns in hydrogen; neither need it be taken from the atmosphere, but from some oxidising substance. The terms "supporter of combustion," and "combustible substance" are merely *relative* terms. Coal-gas burns in air, but air burns just as freely in an atmosphere of coal-gas.

All combustible substances have a *temperature of ignition*, that is, a certain degree of heat must be imparted to them before they begin to burn. This temperature may be very high, as in the case of methane, or it may be so low that the substance ignites spontaneously like phosphorus.

It is scarcely necessary to state that in combustion there is no relation between the heat and light evolved. Thus the intensely hot oxy-hydrogen flame gives off but little light of itself. Similarly, olefiant gas gives a bright light, and methane a practically non-luminous flame at the same temperature. In some cases the luminous flame is due to the incandescence of particles of solid matter, as in the carbons of electric light, the lime of the oxy-hydrogen flame, and in incandescent gas mantles. On the other hand it is sometimes a question of the density of the gas.

The total amount of heat given off during the combustion of any particular body is always the same, no matter how fast or how slowly combustion takes place. A ton of fuel will produce the same quantity of heat in a furnace whether it be consumed by rapid combustion in twelve hours, or by slow combustion in twenty-four hours. Phosphorus yields similar amounts of heat whether it rapidly burns away with

dazzling brightness in oxygen, or is slowly consumed as it glows in air. *See also* **Fuels.**

Combustion Chamber.—The hinder portion of a boiler furnace beyond the end of the fire-grate, in which the gases are burnt.

Coming to Nature. — That stage of puddling in which the sponge or ball begins to assume a pasty condition, the characteristic of malleable iron.

Common.—A prefix that denotes various articles. A common jaw chuck signifies the independent jaw type. Common rafters, the smaller rafters of a roof. A common slide-valve is the D shape, to distinguish it from ported types, balanced types, and Corliss ditto. A common thread is a Whitworth thread.

Commutator.—*See* **Dynamo.**

Compass.—*See* **Dividers.**

Compass Caliper.—*See* **Caliper.**

Compass Saw.—A saw suitable for cutting large sweeps. Its blade is similar to that of a keyhole saw, except that it is larger, and tapers up to a much greater width at the handle. The handle is of the tenon saw type, and is attached to the blade in the same way. Compass saws range from about 10 to 18 inches in length.

Complement.—The complement of an angle is the number of degrees it falls short of a right angle or 90°. The complement of an arc

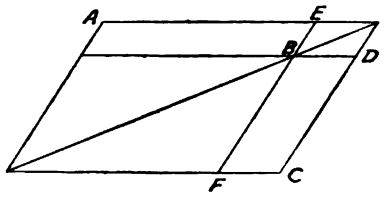


Fig. 36.—Complement.

is the arc by which it falls short of a quadrant. In Euclid the complements of a parallelogram are those parallelograms which touch the diagonal at one point, and are adjacent to the other two contained parallelograms. In Fig. 36, AB, BC are the complements. If either of the parallelograms about the diameter be added to the complements, the figure thus obtained is called the *gnomon*. Thus ED with the complements AB, BC is the gnomon ADF.

Complete Combustion.—When all the separated particles of carbon or other elements in a fuel are perfectly and entirely burnt up, combustion is said to be complete. The prevention of the escape of unconsumed carbon is desirable from two points of view, on the score of economy, and for the avoidance of pollution of the atmosphere. The horrible London pea-soup fog is due to the material particles of carbon, sulphur, &c., belched out by hundreds of thousands of houses, and some 14,500 factories. Dr Shaw estimates that 300 tons of coal are thus lost every day in winter. If only on the ground of economy then it is of prime importance in all engineering processes where combustion is concerned, (*a*) to ensure an ample supply of oxygen for chemical combination with escaping solid particles and gases, and (*b*) to produce sufficient heat to include the temperature of ignition (*see* **Combustion**) of all or nearly all the substances concerned. Where the products of imperfect combustion escape they may be profitably saved, as in the carbon, hydrocarbons, and sulphurous and carbonic acids in blast-furnace processes. To prevent incomplete combustion, furnaces should be supplied with a quantity of air eight or ten times the weight of oxygen which the combustible substance requires for chemical combination. 1 lb. of coal would demand 22 lb. of air with natural draught only. *See* **Smoke Prevention.**

Composition of Forces.—*See* **Forces.**

Compound.—Is a prefix in constant use. It signifies high and low pressure cylinder combinations, as in engines. A lever actuating another lever, as in weigh bridges. A stress which is of two or more kinds, as tensile and torsional, or bending and shearing. A train of gears having four or more wheels in combination, a machine table having two movements at right angles with each other.

Compound Engine.—A compound steam engine is one in which the expansion of steam takes place in a succession of two, three, four, or even five cylinders in series successively of larger size, so arranged that the mean pressure in each cylinder shall be inversely proportional to the volume generated by its piston, thus ensuring equal amounts of work

being derived from each cylinder. The arrangement of the cylinders is very various.

The term compound is usually confined to the engine with two cylinders in series, other compound types being named triple, quadruple, &c., according to the number of cylinders in series.

In a compound or two-series engine, the high-pressure (H.P.) and low-pressure (L.P.) cylinders, or first and second cylinders may be placed side by side to drive two cranks at angles of 90° or 180°. When at 90° there is usually provided an intermediate receiver, which may be heated by a special flue or by a coil of hotter steam. Or the cylinders are placed "tandem" fashion, *i.e.*, one behind the other on the same piston rod. In very large engines the larger cylinder may be replaced by two smaller cylinders, each taking its steam from the first or H.P. cylinder. Two entirely independent engines may be worked compound fashion, a small engine using high-pressure steam exhausting to the main steam pipe of a condensing engine. Old engines of beam and other types have frequently in this way been supplied with steam from newer engines, thus enabling the ad-

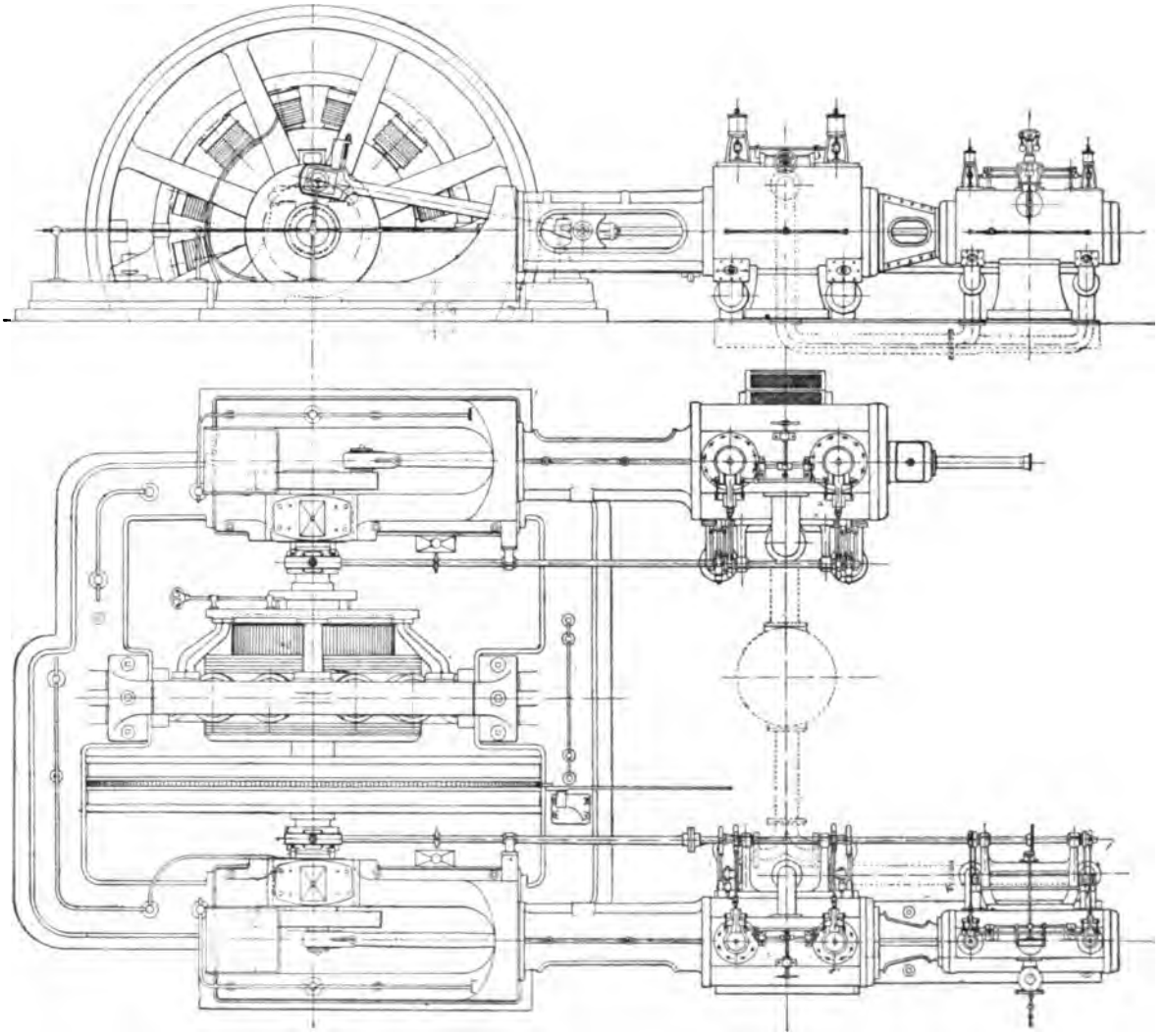
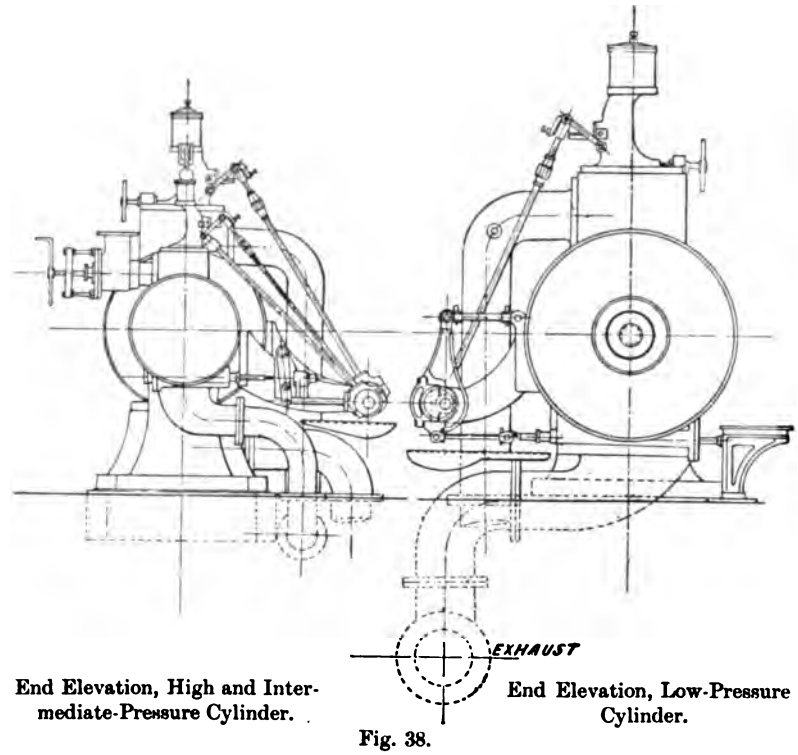


Fig. 37.—Plan of Robey Engine, with Dynamo.



End Elevation, High and Intermediate-Pressure Cylinder.

End Elevation, Low-Pressure Cylinder.

Fig. 38.

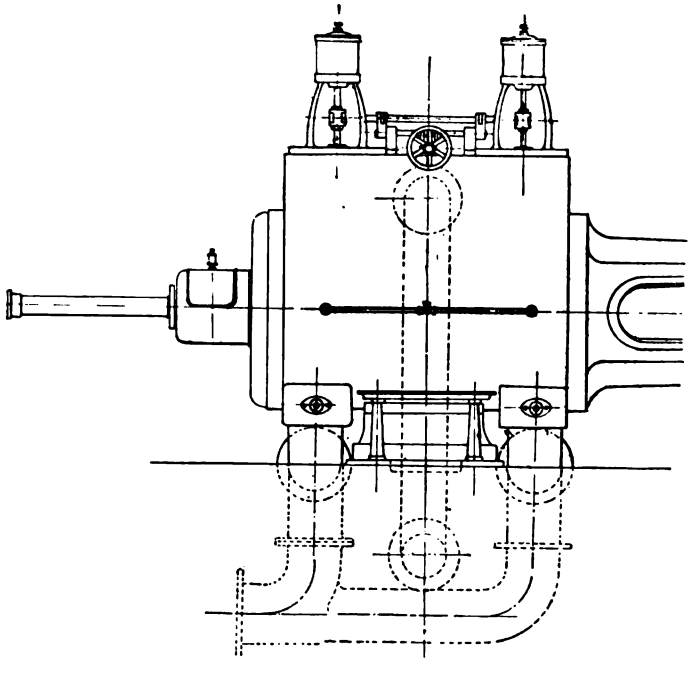


Fig. 39.—Low-Pressure Cylinder.

vantages of new high-pressure boilers to be secured without the cost of replacing the engines, except by the addition of comparatively cheap and small high-pressure engines.

The compound engine is limited in the weight of steam it can use, for it cannot when in economical order and steam-tight, use more steam per stroke than can enter the first or H.P. cylinder. For certain duty, as for electric tramway work, the mean load of which may be only 20 to 30 per cent. of the maximum load, it is clear that an engine large enough to cope with the maximum peaks of load must be much too large for the mean and minimum loads, and therefore not economical. It is consequently doubtful economy to employ compound engines where load factors are poor. It will probably prove more economical to employ simple engines of strong build, arranged to cope with the peaks of occasional maximum intensity by means of full stroke admission, and to run economically on the mean loading. But for steady continuous loads of the cotton-mill or steamship types the compound engine is more economical for various reasons (*see* **Compounding**).

Instead of illustrating the ordinary two-cylinder compound engine, we show a three-cylinder compound (triple-expansion), which possesses advantages for dynamo driving, the whole being

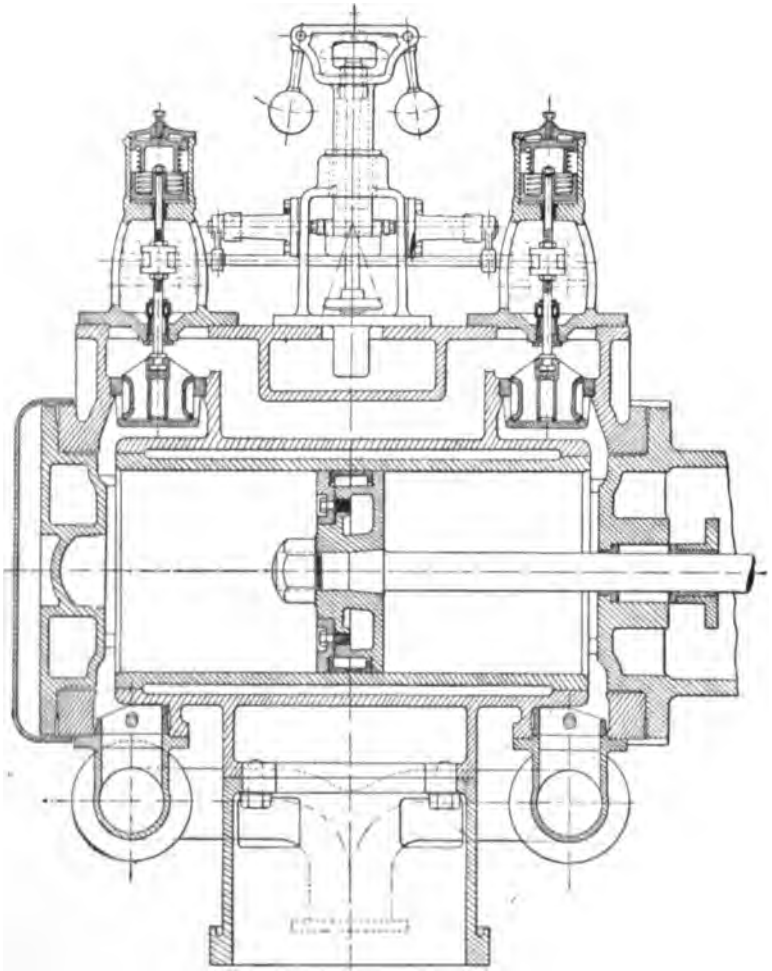


Fig. 40.—Longitudinal Section, High-Pressure Cylinder.

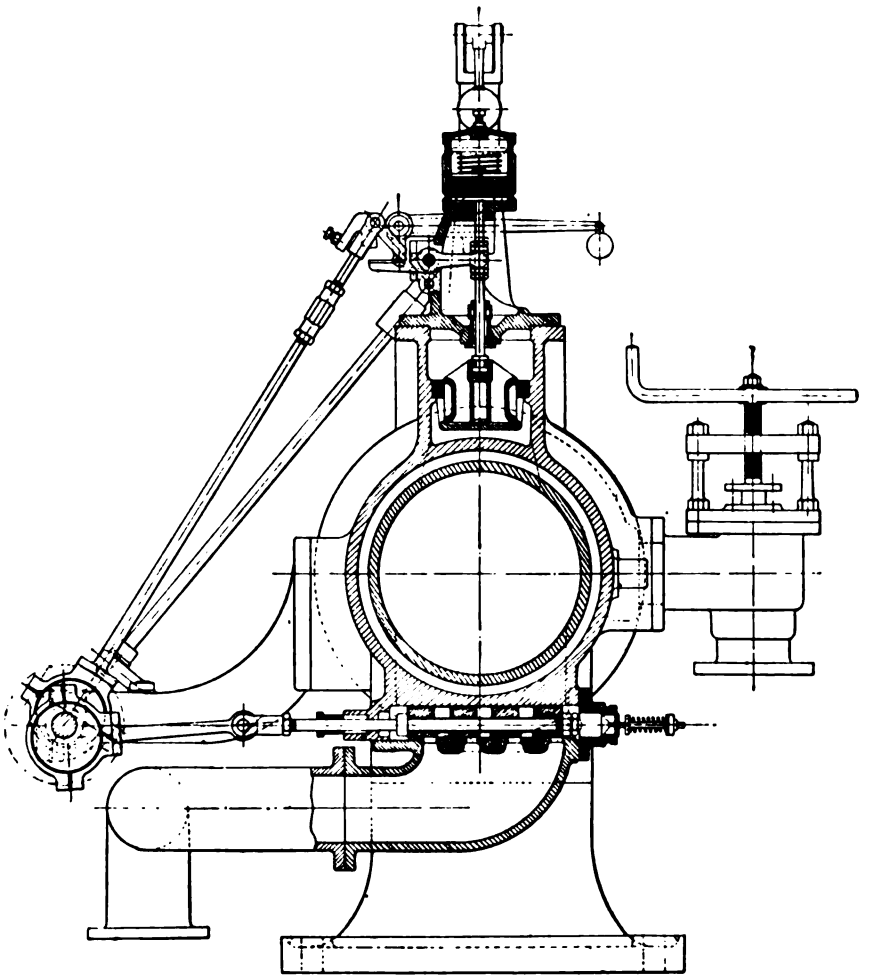


Fig. 41.—Transverse Section, High-Pressure Cylinder.

combined on one bed plate, and which also affords a good example of an automatic trip expansion gear. In Fig. 37 it will be seen that the high and intermediate pressure cylinders are arranged tandem, with the low pressure working on the other crank, the dynamo being fixed between. This represents a type which Messrs Robey & Co., Ltd., have made up to 3,000 HP., but the same engine essentially with the intermediate cylinder omitted has also been fitted to drive a generator. The drawings are largely self-explanatory, but note should be made of the automatic trip gears and drop valves shown in the figures, and in detail, Figs. 40 and 41.

In Fig. 41 the upper eccentric rod acts on the drop valves seen in Figs. 40, 41, by depressing the lever that actuates the valve rod. The eccentric rod lifts the lever, and when the latter is tripped the valve drops, cutting off the steam supply. The governor seen above, in rising moves the lever arm and throws the tripper out of contact. As the governor rises or falls the point of cut-off is thus accelerated or retarded. The exhaust valve seen below is of the gridiron type, but in some cases drop valves are fitted instead.

Of late years the locomotive has been compounded with disputed results in respect of commercial economy, but some of the designs of compound locomotives admit of grave criticism from both an engineering and workshop point of view. *See* **Compound Locomotives.**

Compound Girders.—Girders built up of rolled sections and plates. They are less expensive than girders built of plates and angles, while it is possible to so arrange sections as to obtain strength and stiffness vertically and laterally.

The forms of compound girders are as follows:—A joist or H section is stiffened laterally by a plate riveted on its flange. If more than one plate is riveted on, the strength and stiffness are increased in the vertical direction also; three plates are the usual limit. Two joists are laid side by side and connected by one or more plates riveted to their flanges. In this arrangement lateral strength and stiffness are obtained. Three joists are also connected thus with a top and bottom plate, or plates. Two channels are connected with plates. These are the principal, but joists are also sometimes superimposed vertically. With regard to the relative advantages of these kinds, circumstances must often settle the choice of one in preference to others. General rules are, that though single-webbed girders are accessible for painting, and are economical of material, they do not possess the lateral stiffness of boxed forms. And in all cases the simplest sections should be selected for compounding. Rivets are pitched at about 6-in. centres in compound girders, and are from $\frac{3}{4}$ in. to $\frac{7}{8}$ in. in diameter.

Compounding.—Steam engines are compounded, or so arranged that the steam passes into and expands in a series of two or more cylinders, with the view of more economical results. As steam expands, its temperature varies, and the metal of the cylinder in contact with the steam tends to acquire the temperature of the steam in contact with it. Thus fresh hot steam enters a cooled cylinder, and from 15 to 50 per cent. of it is liquefied. When the exhaust valve opens, the cylinder is hotter than the steam and water, and these are heated by the metal, and in this manner much heat passes uselessly through the cylinder. By dividing the expansion of steam into stages, the range of temperature in any one cylinder is reduced, and condensation is less. Steam condensed in one cylinder is re-evaporated and made to do a certain useful duty in the second or following cylinders. The first or high-pressure cylinder being small, there is a reduced periphery for leakage of steam around the piston and valves; any leakage is trapped in the following cylinder. The H.P. cylinder which takes the first hotter steam is small, and loses less heat by radiation. The mechanical stresses in an engine are less when compounded, and the turning moment is more even.

The cylinders of compound, triple compound, and quadruple compound engines are successively larger as the steam expands, a usual ratio arrived at being to proportion cylinder volumes inversely to the mean pressure so as to obtain equal work from each stage of the expansion. Any cylinder for convenience of arrangement of design may be replaced by two cylinders. Thus a pair of side-by-side engines, with two

cylinders to each crank, may have the high-pressure and one low-pressure cylinder placed on one piston rod to form one side engine, while the intermediate pressure and the other low-pressure cylinder form the other side engine. Here the stream of steam splits into two after the I.P. cylinder, and passes into the two L.P. cylinders.

The main principle in compounding is the reduction of the temperature range in any one cylinder. The receivers between the various cylinders offer a convenient place whence water of condensation may be drained away, or the same re-evaporated by freshly applied heat. Compounding does not increase the power of an engine, but rather renders it impossible to get so much power out of it, because of the limitation placed upon the weight of steam used by the size of the H.P. cylinder. The mean steam pressure in the cylinders of all compound engines is always referred to the L.P. cylinder, and all engines with L.P. cylinders of equal size are of the same power for a given fraction of the L.P. cylinder which is supplied with steam of boiler pressure. Thus a steam admission one-third of the H.P. cylinder is equivalent to an admission of one-ninth of the L.P. cylinder when the cylinder ratios are 1 : 3.

Engines are usually compounded when the boiler pressure exceeds 80 lb., or even 50 lb.; a third cylinder is added over 140 or 160 lb., and a fourth, still smaller first, or H.P. cylinder for pressures of 250, or even 200 lb. In fact, about 50 lb. boiler pressure is approximately allowed for each step in the series, simple, compound, triple, quadruple; the cylinders being named in the last case high-pressure, first intermediate, second intermediate, low-pressure.

Compound Lever.—*See* **Levers.**

Compound Locomotives.—Those in which the steam is made to do duty twice over. After being expanded in the high-pressure cylinder, the steam passes to, and is re-expanded in the low-pressure cylinder, from which it is discharged into the atmosphere. In the case of single-expansion (or non-compound) locomotives, all the cylinders are high-pressure ones, and the steam is exhausted from them into the chimney direct. As in compound locomotives the steam enters the L.P. cylinder at reduced pressure, that cylinder is almost invariably of a correspondingly larger diameter than the H.P. cylinder. In a very few instances it is of the same size, but locomotives so constructed have so far been of a more or less experimental character. The usual ratio of the volume of the H.P. to the L.P. cylinder is approximately 1 : 2½ to 3. The cylinders vary both in number and arrangement. Either two, three, or four cylinders are employed, and of the two last-named designs, several systems have been devised, the cylinders being disposed according to the views of individual designers. The three-cylinder method may consist of two H.P. and one L.P. cylinders, or the reverse; one H.P. and two L.P. cylinders. In the four-cylinder design, two H.P. and two L.P. are used. Appended is a synopsis of the cylinder arrangements and other features of the principal types of compound locomotives.

Space will not admit of a discussion of the merits of these engines. It will be sufficient to say that the object sought and attained by compounding is economy, which may be either direct or indirect. Greater power may be obtained for a given consumption of coal and water as compared with non-compound locomotives; or for a given power, a smaller consumption of fuel and water. In any case, the relative economy is partly due to the higher degree of expansion which is carried out, and partly to the reduction of cylinder condensation, since the difference in the admission and exhaust temperatures of the steam is divided between the H.P. and L.P. cylinders, and is therefore less detrimental than is the case with non-compound engines, in which the steam is expanded once only.

Historically, but not practically, the compound locomotive dates back to 1834, in which year the subject was taken up by Ernest Woolf. Twelve years later—in 1846—Thos. Craddock suggested a four-cylinder compound, and in 1866 Jules Morandière proposed a three-cylinder compound with independent driving wheels. Next came the more practical efforts of J. Nicholson in 1850, and those of J. Samuel in 1852. To Mons. A. Mallet and Mr F. W. Webb, however, belong the credit of applying the compound principle to locomotives in a

really practical manner, the former for two-cylinder engines in 1876, and the latter for three-cylinder engines in 1881. Since that time numerous other compounds, with two, three, or four cylinders, have been introduced by various engineers, and those which have gained some favour, either in the United Kingdom or elsewhere, are mentioned in the subjoined list, to which reference has already been made.

SYNOPSIS OF THE CYLINDER ARRANGEMENTS, &C., OF THE PRINCIPAL TYPES OF COMPOUND LOCOMOTIVES.

Two-Cylinder Compounds.

Mallet, and Worsdell-von-Borries Systems.—One H.P. and one L.P. cylinder, placed either inside or outside the frames. Provision made for admission of boiler steam to L.P. cylinder direct, to assist engine in starting, or in case L.P. crank is on a dead centre.

In some two-cylinder compounds, the driver can work the engine non-compound at will.

Three-Cylinder Compounds.

Webb System.—Two H.P. cylinders outside the frames, and fixed a short distance behind the smoke-box, and one L.P. cylinder between the frames, and immediately under the smoke-box. H.P. and L.P. pistons drive separate axles, which are non-coupled. Cut-off for H.P. cylinders variable; for L.P., fixed by loose eccentric.

Smith System.—One H.P. cylinder inside the frames, and two L.P. cylinders outside. All three connecting rods may drive the same axle, or the H.P. and L.P. rods may drive separate axles. Relative cut-off for H.P. and L.P. cylinders either definitely variable, or independent, as designer thinks fit. Three sets of valve gear. L.P. cranks set at an angle of 90° to one another; H.P. crank at 135° to L.P. cranks. Engine can be worked as a compound, semi-compound, or non-compound.

Four-Cylinder Compounds.

Webb System.—Two H.P. cylinders outside, and two L.P. cylinders inside, all in line transversely, and all driving on to the same axle. Two sets of valve gear for working four valves; therefore cut-off for H.P. and L.P. cylinders non-independent.

The above system has since been modified by Mr Geo. Whale, the present Chief Mechanical Engineer of the L. & N.W.R., who has fitted the H.P. cylinders with separate sets of valve gear in order that the cut-off may be independent.

Von Borries System.—Two H.P. cylinders inside, and two L.P. outside the frames; all four in line, and driving on to the same axle. Two sets of valve gear for working four valves. Non-independent cut-off for H.P. and L.P. cylinders.

Vauclain (1889) *System.*—All four cylinders outside the frames, one H.P. and one L.P. on each side. The respective cylinders are superimposed, the H.P. being cast in one with the L.P., and arranged either above or below it as circumstances require. The two pistons on each are connected to the same crosshead, and therefore drive the same axle. Consequently, cut-off is non-independent. Two sets of valve gear and two valves.

Vauclain (1900) *System.*—Two H.P. cylinders between the frames, and two L.P. cylinders outside; all four arranged in line, and driving the same axle. Two valves, two sets of valve gear; therefore cut-off non-independent. In a recent variation of the above 1900 system, the H.P. and L.P. pistons drive separate axles.

De Glehn System.—Generally, two H.P. cylinders outside the frames, and placed a short distance behind the smoke-box; and two L.P. cylinders between the frames, and under the smoke-box. This arrangement is not only reversed when necessary (as in the case of goods engines with small driving wheels), but the cylinders are also all placed in line with the smoke-box. Four valves and four sets of valve gear. Independent cut-off for H.P. and L.P. cylinders. The H.P. and L.P. invariably drive separate axles, and the driving wheels are coupled by outside rods. Engine can be worked non-compound.

Plancher (*Italian*) *System.*—In this system the two H.P. cylinders are both on one side of the engine, and the two L.P. cylinders are on the other, all four being in the same horizontal plane, and in front of the smoke-box. Thus, there is one H.P. cylinder outside and another inside the frame on the same side. On the opposite side, the L.P. cylinders are similarly arranged.

Two valves, therefore two sets of valve gear, and non-independent cut-off.

Cole System.—The two H.P. cylinders are between the frames, but are placed ahead of the smoke-box; the two L.P. are outside the frames and in line with the smoke-box. The H.P. and the L.P. pistons drive separate axles, which are coupled. Four valves, but the H.P. and L.P. valves on each side are worked by one valve rod, so that there are only two sets of valve gear, with non-independent cut-off. In another Cole system the four cylinders are placed in the same horizontal plane, and the four connecting rods drive the same pair of wheels.

Vauclain Tandem System.—All four cylinders are outside the frames. Each H.P. cylinder is directly in front of and bolted to its fellow L.P. cylinder, tandemwise. The piston rods of the H.P. pistons are connected to the L.P. pistons, and work through the joint cylinder covers. Four valves, but only two sets of valve gear, as the H.P. and L.P. valves on each side are operated together. Therefore cut-off non-independent.

Mallet Articulated System.—All four cylinders outside the frames. The H.P. pair and L.P. pair are arranged in two distinct sets; the two L.P. cylinders being at the leading end of the engine, and the two H.P. at about midway in the boiler length. Each pair drives a separate group of wheels. The two groups of driving wheels are unconnected with each other, and the front group of wheels is usually constructed on a swivelling plan in order to facilitate the running of the engine on curves. Four valves and four sets of valve gear. Engine can be worked as a non-compound.

With the exception of the Webb four-cylinder engines, nearly all compounds are now fitted with devices for admitting live steam (generally at a reduced pressure) to the L.P. cylinders, to provide greater power at starting, or when ascending steep inclines. In another four-cylinder system, known as the Golsdorf, and not mentioned in the above list, the engine works non-compound when the reversing lever is in full gear, giving a cut-off of about 70 per cent. Steam then passes to the L.P. cylinders through ports in the L.P. valve face. As soon as the engine is linked up these ports are closed. The inside cranks of the majority of four-cylinder compounds are at right angles to one another, while each of the outside cranks is opposite the inside crank on the same side.

Compound Slide-Rest.—The object of this rest is to provide two movements at right angles to each other, or at any desired angles by means of the swivel base, to turn or bore tapers. Examples of the rest occur in various lathes shown in these volumes. A marked difference between English and American lathe practice has been the small extent to which the compound rest is applied in the latter country, while in England it is nearly universal. The absence of the top longitudinal slide (which leaves a "plain" rest) means that parallel work can only be turned by moving the entire saddle or carriage along the bed, which is not a very precise way sometimes for fine work; and that short steep tapers cannot be produced unless a taper attachment is fitted. The compound rest, however, is finding more favour now in America, being seen much oftener than hitherto.

Compressed Air.—Compressed air is used for transmitting power in mines, for driving machines, and certain tools. When air is compressed by mechanical power it will, when free to do so, return a portion of the power expended in compressing it, and this may be used for driving engines, for working hammers, drills, &c. The whole of the power expended in compressing the air cannot be recovered in the motor, partly because of the energy expended in overcoming the friction of the compressor, and the pipes used to transmit the air to the motor, partly because of the leakage of air that always takes place, and particularly in mines, but principally because of the heat that is generated in the act of compression. The most economical arrangement where compressed air is employed, would be isothermal compression, where the whole of the heat is removed as fast as it is generated, because the air in the cylinder expands as its temperature rises, and more work has therefore to be done upon it to obtain a given pressure when referred to ordinary atmospheric air, or free air, as it is called. Isothermal compression is not practicable, but the nearer it is approached, the more efficient is the transmission. What is called

adiabatic compression, in which none of the heat generated in the act of compression is lost, and none gained, is also impracticable, as there is always a loss of heat from the cylinder walls. The loss in compression is never less than 20 per cent. under the best conditions, quite apart from that due to friction, and to the losses in the driving engine. There are also losses when the air is used to do work, and it may safely be stated that the whole of the losses are never less than $33\frac{1}{3}$ per cent., or the efficiency greater than $66\frac{2}{3}$ per cent., while in practice it is often as low as 25 per cent., particularly in mines. The efficiency of compressed air transmission may be greatly increased, where it can be employed, by reheating the air, near the point of consumption. The question of the efficiency of compressed air turns very largely upon the temperature at which the air is compressed, and the heat that it is possible to apply before the air is made to do work. *See* **Air Compressor.**

Compressibility.—The degree to which this property exists in different bodies varies widely. Of the three kinds of matter, gaseous, liquid, and solid, the first named is most compressible, and the volume occupied by a gas is inversely proportional to the pressure (Boyle's Law). The unit of pressure is one atmosphere or 14·73 lb. per square inch, and by increasing pressure the gas ultimately becomes liquid. Temperature, however, is also an important factor, for it has been found that though some gases, such as oxygen and hydrogen, refused to liquefy even under a pressure of 3,000 atmospheres, they readily did so under a tenth of that pressure, when cooled below certain temperatures. This temperature for each gas is called its *critical temperature.* Oxygen is liquefied under a pressure of 320 atmospheres at – 140°; air under 39 atmospheres below – 140°. In many cases, however, the critical temperature is at the ordinary temperature of the air, as in ammonia. Liquids are but slightly compressible, a pressure of 22 atmospheres or .324 lb. per square inch, merely diminishing the volume of water by a thousandth part. Mercury is the least compressible of liquids, its compressibility being but one-sixteenth that of water. Solids are but slightly compressible, indiarubber and cork being more so than most solids. The compressibility of steel is about one-seventieth that of water.

Compression Coupling. — A cone vice coupling.

Compression.—A term in frequent use to denote the stress which is of a crushing character. It applies to the compression stroke of a gas-engine piston, the strength of a material to resist compression, and to the line of compression in an indicator diagram.

Concave Saw.—A circular saw of dished form, so forming a portion of the envelope of a sphere. Used for sawing the felloes of wheels. Two saws are used in pairs, cutting the inside and outside of a felloe from a piece of wood on a carriage presented to the saw at an angle with its axis.

Concentrated Load.—*See* **Beam, Beams of Uniform Strength.**

Concentrating Machinery.—Covers a number of machines used for concentrating the tailings of ores. It includes coarse and fine concentration, and wet and dry methods. The old-fashioned buddle is often employed. There are also the shaking or percussion tables suspended from rods at an angle, and reciprocated alternately by a cam and spring. The sluices are carried off by a flow of water. The vanner is a machine in which the ore is carried along by a broad indiarubber band. Jets of water separate and keep back the lighter portions, while the heavier parts travel onwards to a receiver. Centrifugal concentrators are used in which the heavier particles are driven to the outside of a pan, the lighter ones dropping through a central discharge area. In dry machines the pulverised ore is fed through a hopper, and exposed to the action of a strong current of air from a blower fan which drives them against a perforated jigging screen, with provision for separating the heavy and light particles. Adjuncts to concentrating machines are the screens for the sizing and classification of particles, of which the revolving trommels in their various forms are the best known.

Concentric Chuck.—*See* **Lathe Chucks.**

Concrete.—Concrete is generally a mixture of broken stone, brick, clinkers, or other clean substances, free from clay or loam, or dirt; with sand, and Portland cement. If the *aggregate,* as

the above substances are termed, is strong and tough, and every surface is coated with cement, the resulting concrete is exceedingly strong and tough, for the adhesion of the cement is such that a bar of concrete when broken will break through the aggregate rather than through the contact surfaces.

In order to find the proportion of broken stone, sand, and cement that must be observed, a quantity of the broken stone is weighed into a vessel, and water is poured in just sufficient to cover it. The weight or volume of added water is noted, and a similar measure of water is filled into an empty vessel, and the level is marked. The water being discharged, the sand is then filled in to this level and measured. This measure of sand is that weight necessary to fill the voids in the larger aggregate. Into this dry sand water is then poured, until the water shows freely on the top of the sand. Then the bulk of this water is the bulk of the cement necessary to be added.

Both the sand and the cement ought to be in excess of the quantities thus found, in order that the resulting concrete may be free of all voids. In mixing concrete, the broken stone is laid in a flat heap on a clean floor, and the proportions of sand and cement are spread over the heap, which is then turned over dry by men with shovels. A skilled shovel-man will contrive in this work to distribute the sand and cement very well. A second turning over at right angles to the direction of the first is usually considered sufficient. Water is then sprinkled on—it should come from a fine rose, but as often as not it is splashed in mass out of a pail—and the wet mass is again turned over and chopped until every part is equally moist. When carefully mixed the concrete may be filled into place, and should be well rammed, so that if put into place fairly loose and crumbly, the act of ramming shall so consolidate the mass as to cause the water to flush out on the surface, thus proving a sufficiency of water even if the mixture was only crumbly before ramming. Some engineers prefer to put concrete in place in a sloppy state, ramming it into corners, and this appears better calculated to produce water-tight work. Concrete put down under water should not pass loosely through the water, which would wash out the cement. This difficulty is got over by putting the cement in bags. *See* **Bag Work**. These are often left, but if at the bottom of still water, the bag may be contrived with a slip tie, so that when lowered to place the bag may be released and drawn up, leaving the concrete quietly in place, or a box with hinged flap bottom may be employed.

Better results may be obtained in mixing concrete when the sand and cement are first mixed. Twice turning over will suffice, with once turning over when the aggregate is added. It is particularly to be noted that when the minimum quantity of sand and cement is added to, say, one cubic yard of broken stone, the result should be only a cubic yard of concrete free from voids. To ensure that there is mortar sufficient, however, the mixture of sand and cement ought to be added to the extent of 10 per cent. additional.

For the best results, both the aggregate and the sand should be washed to free them from argillaceous or other improper matter. In constructing large work an economy of mortar is secured by the use of large lumps of stone placed here and there in the mass, and known as *plums* by the workmen. These must be clean and well mortared over. In extensive work concrete is mixed by machinery, *see* **Concrete Mixers**, but this must be good since much mechanical mixing has been faulty.

In what may be termed concrete masonry, such as the Vyrnwy Dam, every stone was separately set in a bed of soft mortar, and smaller stones were fitted into the voids, and driven in with wooden mallets. No coursing was attempted, but the whole surface is a mass of irregular projecting stones, many of which may weigh tons. A dam so constructed is practically monolithic, and unlikely to develop either horizontal or vertical shear planes.

For all ordinary work there is no objection to round pebble gravel as the aggregate of concrete, but for special work round pebbles ought to be broken into rough pieces. Limestone chips do not make good concrete, owing, perhaps to the fact that Portland cement is a calcareous cement, which unites better with silicious substances. A useful concrete is made with coke breeze for floor purposes. It will take and hold nails.

Houses may be built of concrete, the aggregate of which is burned ballast. Fine concrete is made from crushed granite, and moulded into flagstones for paving purposes, and the artificial stones generally are Portland cement concretes. *See* **Cement.**

Mr Harrison Hayter was one of the first to explain the reasons of failures in concrete work. He and others had observed that such work, though performed with every precaution by engineers of eminence, frequently cracked, lifted in some cases an inch or two, and that pieces flaked off the faces. When this happened a white substance of the consistency of cream was found in the newly exposed concrete. The same thing had been noticed by French engineers. Mr Hayter following M. Lechartier, a French engineer, ascertained experimentally that in all cases magnesia was present in considerable quantities, and that the cream-like substance referred to contained about 80 per cent. of magnesian hydrate, consisting of about two-thirds magnesian oxide (magnesia) and about one-third water. The magnesia was present in the Portland cement used in the concrete. Its presence does not prevent the concrete from setting, but after a while its natural affinity for water causes absorption of the latter, with the disintegration of the concrete. The action goes on more rapidly in water than in air.

Another substance which is injurious in cement is carbonate of lime. This, too, does not prevent the setting of the concrete, but after a while any free lime which has not entered into combination with alumina present absorbs carbonic acid from the atmosphere, becoming carbonate of lime, which remaining inert in the cement detracts from its strength. For these reasons a chemical test is as essential as a mechanical one. Mr Hayter has expressed the opinion that 95 per cent. of ground Portland cement should pass through a 50-in. sieve, that is one having 2,500 holes to the square inch, that the remaining 5 per cent. should pass through a sieve of 1,000 or 1,500 holes to the inch, and any that would not go through this should be thrown aside. His idea of the proper chemical composition was :—Lime, 50 per cent.; silica, 30 to 35 per cent.; alumina and oxides of iron, 13 to 15 per cent.; and that magnesia should on no account exceed 1 per cent.

Concrete Blocks.—Concrete work includes the use of moulded concrete blocks, concrete deposited in bags, grouting, monolithic work, combination methods, and reinforced or armoured concrete.

The usual proportions for concrete blocks are one part of cement, to from six to seven parts of sand and gravel. But in exposed situations the proportions of cement must be increased, while in still water it may be diminished. The proportions used for the interior and the exterior of structures are also varied. Thus the former may be one of cement to eight of sand and gravel, and the latter one to five or six. In settling the proportions of cement to rubble and sand used in making concrete, every engineer is prepared to swear by his own experience. But a safe general rule is that larger proportions of cement must be used in exposed situations than in those which are well protected.

Lava has been used successfully for concrete blocks in a breakwater at the island of Grand Canary. The composition in a thirty-ton block was 3·92 cubic yards of lava, 9·16 of sand, and 0·46 of Portland cement. The above formed a cementing material which was incorporated with 15·08 cubic yards of block lava and rough gravel. The blocks took from four to six months to harden.

It is necessary that the mixing be accomplished quickly in order to prevent local setting of the concrete. The amalgamation must also be thorough. The imperative demand for machines that arose in the sixties, when block work was first being attempted, has been productive of numerous types in which the objects desired have been arrived at by different methods. *See* **Concrete Mixers.**

Before blocks are laid, a level bed is prepared by dredging down to the solid rock, and on this a concrete foundation is laid, and over this solid blocks of concrete. These blocks are fitted to one another, and all cemented at their joints, so that when set, the breakwater or harbour wall or pier is practically one solid mass. All the blocks are set and cemented by divers, so that there is no chance work, but the details are seen as well as though on *terra firma*.

Blocks are laid horizontally, or inclined. The inclined system, introduced by Mr Parkes at Karachi, had also been adopted early in the nineteenth century at Ardrossan harbour, where stones 6 ft. to 10 ft. long, and 3 ft. to 4 ft. wide were laid in a sloping direction across the length of the pier. The system was adopted also at Colombo, the idea being to offer a better resistance to the force of the monsoons. At Colombo the blocks were set at an angle of 68° with the horizontal, corresponding with an inclination of one in three, sloping away from the sea. These were of course laid at their proper slant on the block trucks, and lifted at that angle with Lewis bars. These blocks were joggled with plastic cement in bags, rammed into grooves in their abutting faces.

The harbour works at Colombo afford a very fine example of concrete block work. Lying in an exceedingly exposed situation, they are open to the full fury of the south-west monsoons in the months of May and June. A long ocean swell dashes itself simultaneously on a length of about 3,000 feet of breakwater, causing the top of the water to rise to a height of 120 ft. above sea level, and sometimes to 150 ft. This goes on for a period of about six weeks. But the breakwater has now defied the monsoons for over twenty years, and has made Colombo a safe port of call for the vessels trading with the Far East and the Antipodes.

These piers are built out in various ways. *See* **Block Work.** The Titan crane picks the blocks up, and runs out with them over the sea, and deposits them in place two or three fathoms deep by the assistance of divers, between whom and the men in a boat signals are given and received. As the blocks extend seawards the rails for the locomotive and crane are laid on the completed portions, until the whole length of half a mile, a mile, or two miles is completed. The vast stretch of the arm of the crane, of forty, fifty, sixty feet, permits it to lower the blocks in the deep sea while the framework of the crane and its wheels are still supported solidly behind the scar end of the work on the broad solid wall.

Settlement to a certain amount takes place in concrete blocks, varying from 1 in. or 2 in. to as much as 18 in. Some of this is due to the weight of the travelling cranes and trucks, some to the action of the sea.

Harbour piers have been made with concrete alone, as at Blyth, Wicklow, and Skinnington. The concrete has been deposited like rubble, and hardening under water, has formed piers several hundreds of feet long, becoming practically a solid mass of stone. *See* **Monolithic Work.** One reason why some engineers prefer concrete in mass to concrete in blocks is that the joints in the latter may, and have in some instances proved sources of weakness. A small crack or opening becomes enlarged by the wearing action of the sea, and in concrete block work the joints are very numerous. This is one reason why large blocks are preferred to small ones, 40-ton blocks being a common size. And the joints are also bonded by means of joggles formed by pouring grouting or liquid cement into grooves on opposed faces.

In many cases concrete piers are built on a rubble foundation, thrown in and allowed to assume its natural slope. A solid pier of concrete blocks may be built on this, or pier facings with a concrete hearting. Rubble is carried some distance up the facings of the piers to serve as a protection against storms, and concrete in bags is in some cases deposited on the rubble next the face of the pier on the seaward side. *See* **Bag Work.** A breakwater at Bilbao harbour is laid on a rubble mound, covered with loose blocks of concrete weighing from 60 to 100 tons each, filled in with rubble upon which a layer of concrete is levelled, and on this the walls of concrete blocks are built, enclosing concrete laid in mass.

When a hearting has been laid, the outside faces and the top are lined with great blocks of squared masonry, cemented or bonded together in various ways.

Concrete copings and facings are not so strong and durable as rubble granite, united with Portland cement. Roman cement has also been used as a bond with good results.

Bags of cement have been used for joggling concrete blocks after setting, the grooves running longitudinally down the meeting faces of the blocks, and the bags being rammed in at high water. This plan was adopted at Colombo and elsewhere.

Foundation cylinders are made of concrete. They are built one over the other as sinking proceeds, as in the case of cast iron, and are filled in with plastic concrete. A concrete wall is built on these. This device is not suitable for walls in exposed situations, but only in comparatively quiet water, and in dock work. A wharf wall at Colombo 829 ft. long is built on a double row of cylinders 5 ft. and 7 ft. diameter, sunk 16 ft. and 28 ft. deep below low water. The cylinders are in sections, the 5 ft., being 3 ft. 6 in. deep, the 7 ft., 4 ft. 10 in. deep. The holes in the first are 3 ft. in diameter, those in the second 4 ft. 6 in. The first weigh 3 tons each, the second 7 tons.

The increasing employment of concrete as a material for building construction is to be noted. A bridge built over the Tay in 1905 is one example only of a bridge built wholly of concrete, but faced with red freestone, which gives it the appearance of a stone bridge. It has six arches of 6 ft. 6 in. span, the width between parapets is 16 ft. *See* **Armoured Concrete.**

Concrete Mixers.—Concrete has taken a place of so great importance that its preparation has called into existence a large number of machines of diverse types, operated by hand, and by power; and intermittent, or continuous in action. Both systems are of much value, each in its sphere. In the intermittent type, the machine has to be stopped for the insertion and ejection of every separate charge. In the continuous type, no such stoppage is necessary. This classification is of the broadest character, since each great group includes numerous designs, as follows :—

The Messent.—This is a machine of the intermittent type, one of the oldest, and best. The mixer is a hollow box of polygonal form, Fig. 42, Plate III., without blades, which as a design stands by itself. It was the invention of the late Mr Messent, for many years the engineer to the Tyne Commissioners. Its facets, by the rotation of the shaft on which it is keyed, throw the materials over from one side to the other, as fast as they are brought up above the centre. As this occurs several times during a revolution the mixing is thoroughly accomplished in from six to twelve revolutions, the conclusion of which for any mixture is indicated by a tell-tale. A doorway is formed in one side, through which the materials are shot from a hopper swung over the machine, or from a platform above the mixer, the latter being preferable. The concrete is dropped into skips, or into the block moulds direct, if the mixer is fitted on a truck for travelling.

Hand, steam, and electricity are used for rotating, and also for travelling. Capacities range from a half cubic yard to two cubic yards.

The latest development of the Messent mixer is due to Mr A. H. Owles, M.I.C.E., and is that illustrated in Fig. 42, Plate III. The mixing vessel is of the standard Messent type, and is mounted upon a steel framed carriage, with steel wheels and spring bearings. Two electric motors are provided, one to revolve the mixer body and one to propel the machine along the track; by this provision the operations of mixing and travelling are carried out simultaneously. The proper charges of material are fed into the mixer from hoppers, the charging door is closed, and the machine travels to, and over the block mould. The vessel being rotated at the same time, the number of revolutions of the mixer is indicated by a dial, and when fifteen revolutions are recorded the mixture is complete, the door is opened and the concrete discharged into the block mould, and the machine returns for another charge. The speed of travelling is six miles per hour; powerful foot-operated brakes are fitted to the mixer and travelling gear. The output of a 1 cubic yard machine is about 120 cubic yards per day of ten hours.

In America machines of cubical form are used, but there are none having the peculiar facets of the Messent.

The Ridley Mixer.—This is one of that large type in which a cylinder is used for the body. Special features are the inclined position of the cylinder, and four flat plates attached to arms which lift the material from the bottom and carry it up well above the centre, whence it slides down and drops a little further down the cylinder. Lifting thus occurs four times during a revolution. The machine makes from 12 to 15 revolutions per minute. The action is continuous, there is a hopper at the upper end, and a discharge shoot at the lower. The



Fig. 42.—Electric Travelling Concrete Mixer.



Fig. 43.—Electric Concrete Mixer with Elevator.
(Jessop & Appleby Bros., Ltd.)



Fig. 44.—Portable Concrete Mixer
(Thos. C. Fawcett, Ltd.)



Fig. 46.—Portable Concrete Mixer.
(Arthur Koppel.)

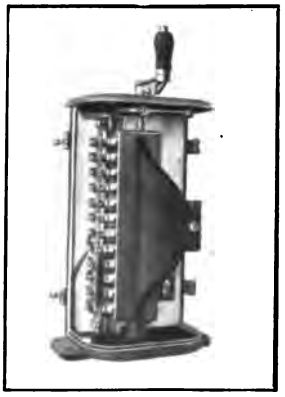


Fig. 62.—Drum Type Controller.



Fig. 63.—Drum Type Controller, Fireproof Chamber Swung Back.
(The Electric and Ordnance Accessories Co., Ltd.)

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cylinder is driven by a belt and bevel gears at the lower end, and is mounted on wheels to be located where wanted.

The Taylor Mixer.—This comprises two conic frustra meeting by their bases, and rotating on a horizontal axis, throwing the material from their sloping sides.

The Carey-Latham.—This is one of the best mixers, having a large capacity for output. It has a cylinder set horizontally, Fig. 43, Plate III., and revolving on rollers carried in cradles, the rollers making frictional contact with belts that encircle the mixer body. The interior has inclined blades or vanes, attached to the shaft. Although both these and the cylinder revolve in the same direction, their movements are independent, the vanes rotating at a slightly slower speed than the cylinder. The result is that in addition to throwing the material, they scrape the interior surface, and prevent the concrete from lodging there.

Another valuable feature embodied in this machine relates to the admixture of the water. In many machines this is introduced along with the solid ingredients. In the Carey-Latham the materials are amalgamated first, and then the water is introduced in a spray from the central shaft. The advantage is that none of the water runs out to be lost before the mixing is complete.

Messrs Jessop & Appleby Bros., Ltd., have improved on the earlier crane and platform feeding arrangements of this machine. Ladder and bucket elevators are used, see Fig. 43, Plate III., one on each side of the machine, for the sand and broken stone respectively. The cement also is both supplied and measured by a feeding screw, and the speed of the screw can be varied within wide limits. This exact mechanical regulation of measurement, combined with the elevating devices, and the electric drive also fitted, complete, and render an originally good machine of the highest value. The output of this machine is about 20 cubic yards per hour.

Fawcett Machine.—In this, Fig. 44, Plate III., the mixer is an open trough which leaves the mixture open to observation, and within which two rotating axles carry flat arms or paddles with claws at their extremities, which act as scrapers, Fig. 45. The axles rotate in opposite directions, and the paddles are arranged to "hit and miss" in the spaces. The mixer is fed from an elevating box brought up an incline by power, and controlled by a lever. The concrete is discharged into a tipping wagon brought on rails underneath the machine. In this design

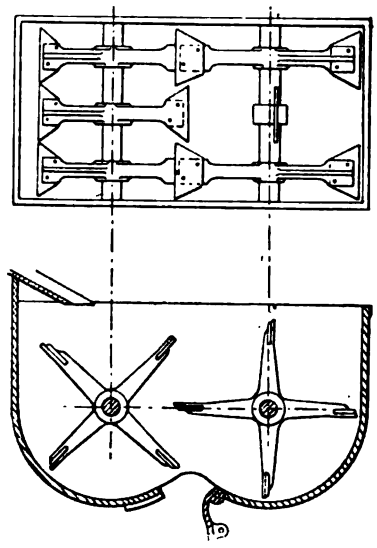


Fig. 45.—Paddles of Fawcett Mixer.

machines are made having capacities of from 100 cubic yards to 300 cubic yards per day of ten hours.

The Gauhe Mixer.—This is one of Continental design, by Arthur Koppel, Fig. 46, Plate III. The body, compare with the detailed drawing Fig. 47, is a cylindrical drum rotating on a horizontal axis, and having the shaft fitted with blades arranged in a slanting position. The body has end plates of cast iron A A around which the cylinder of steel sheet is bolted. The material is lifted by the blades B, and falls by gravity. Provision is made for scraping the interior by the frame C, which swings loosely on the revolving shaft. The driving mechanism is shown to the right of Fig. 47. It takes place from the shaft E, driven from the belt pulley D having its loose pulley, whence through the clutched bevel pinion F the wheel G on the mixer shaft is operated.

The object of the coned clutch is to drive the elevating gear by which the charges are fed

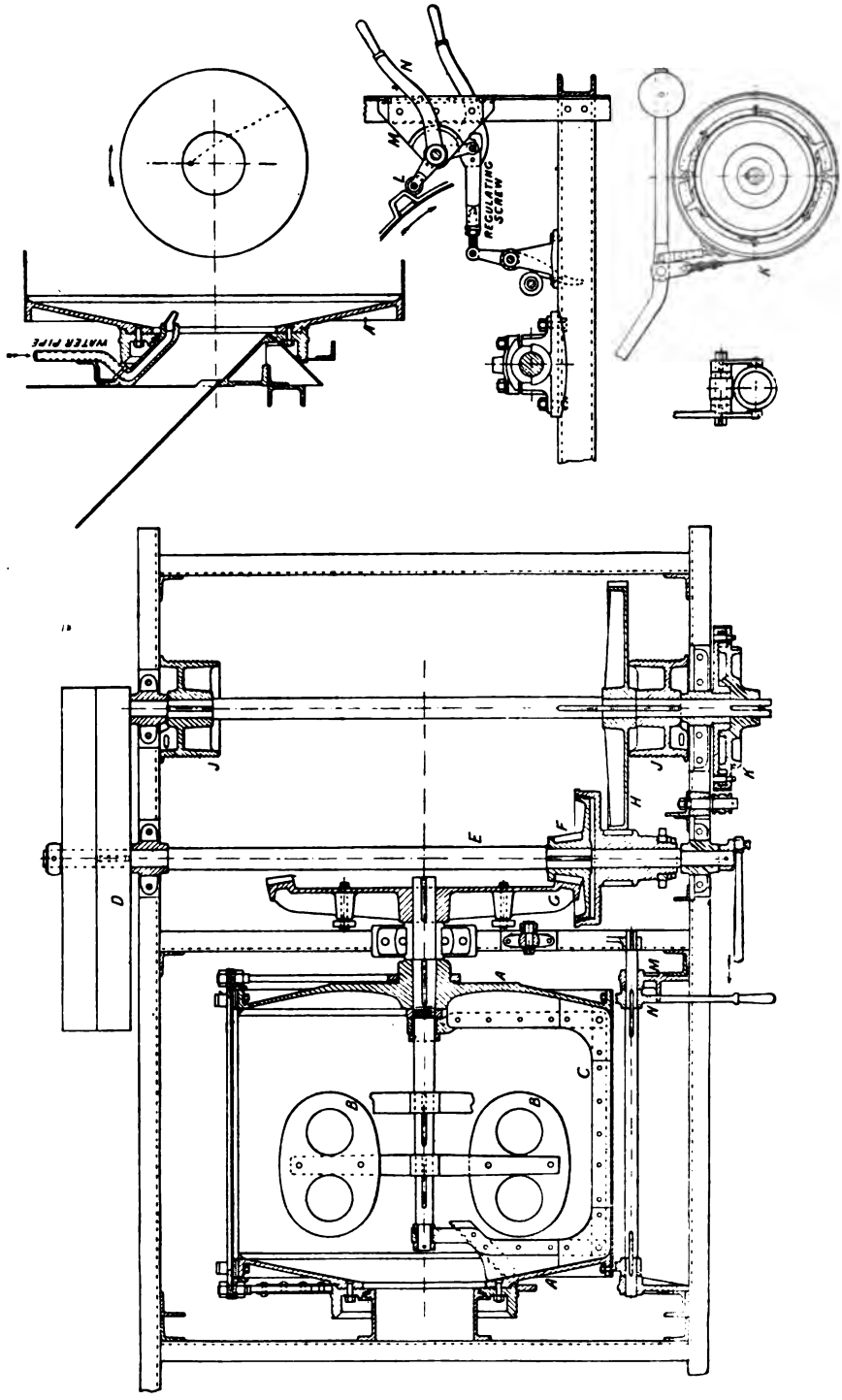


Fig. 47.—Details of Gauhe Mixer.

into the hopper of the machine. The spur wheel H, driven from the clutch pinion, actuates the two grooved rope drums J J. This is being done while a charge is mixing. The braking gear K is also controlled by a lever. By this mechanism the elevator box, after being charged, is lifted up the framing, and round curved guides, tipping its contents into the feed hopper. This has a shaking movement, the object of which is to prevent the mouth of the mixer from becoming choked up. In this machine the mixing is first done dry, and wet afterwards.

As the cover of the mixer has to be removed for the discharge, there is a mechanism by which this is done without stopping the mixer. By pushing a lever, N, pivoted in M, rollers, L, are brought into contact with projections on the door, so arresting the movement of the latter, while the mixer passes on, discharging its contents. When the drum comes round next, it throws the lever back, and the cover again closes, and rotates with the drum.

There is also another group termed *Gravity Mixers*, in which the material falls vertically by gravity as it is mixed.

Condenser.—The condenser of a steam engine is a vessel in which the steam that has done work in the cylinder is cooled and reduced to water, whereby the pressure of the atmosphere is enabled to act usefully on the piston and do work. The non-condensible air which enters the condenser with the steam is removed by the air pump. *See* **Air Pump.** Condensers are of two principal orders, jet, and surface.

In the jet condenser the steam to be condensed is played upon by a constant jet or spray of cold water, and both the condensed steam and the cooling water must be removed together. This is the most efficient type of condenser, though there is more air to be dealt with by the air pump.

The surface condenser is necessary where the cooling water is impure, as at sea, where it is essential to carefully conserve the pure condensed steam. The steam to be condensed is made to pass through a vessel containing a large surface of small brass tubes through which the cooling water is forced by the **Circulating Pump.**

The barometric condenser, Fig. 48, is a jet condenser placed at the top of a drop pipe 30 ft. to 40 ft. high, thus avoiding the use of the pump for removing water, which removes itself by gravity down the barometric drop pipe. Air is removed from this condenser by the air pump, *via* B, through a supplementary air cooler, D. Or it is drawn out by the eductive action of the falling stream of water after the manner of the ejector condenser, which is constructed on the principle of the injector, and is supplied with its stream of water *via* C and G at a velocity equal to that

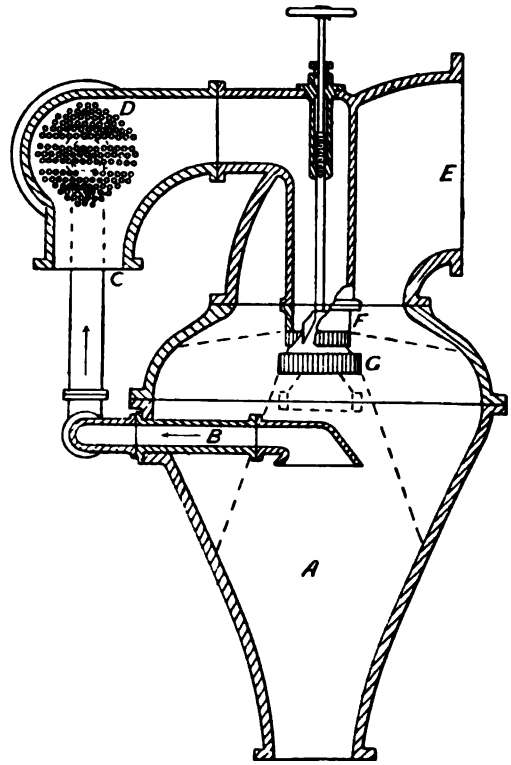


Fig. 48.—Barometric Condenser.

given by a head of, preferably, not under 15 ft. The vacuum formed in the chamber A produces a rapid flow of exhaust steam *via* E, which communicates its momentum to the water, and produces a joint velocity equivalent to a head representing about 12 lb. of vacuum.

The economy derivable from condensing is represented by $\left(\frac{P + V}{P}\right) - 1$, approximately when P is the mean pressure of steam in a non-condensing engine, and V is the amount of

"vacuum" secured by the condenser. From this gross economy must be subtracted the energy required to drive the air pump; and commercially, of course, interest and depreciation must be allowed for in respect of the condensing plant outlay and the reduced outlay on boiler plant.

In a surface condenser the brass tubes are $\frac{5}{8}$ in. to $\frac{3}{4}$ in. diameter, and about 10 lb. of steam per hour may be condensed for each square foot of tube surface.

By Dalton's law of mixed vapours the pressure of air and vapour in a condenser is the sum of the pressure that would be exerted by the air if alone present, and the pressure proper to the temperature of the water vapour. At any given temperature of water, a space of say one cubic foot above that water will contain a given weight of water vapour, no matter how much air be present. If, therefore, the pressure in a condenser be greater than that proper to the temperature of the water the excess is due to the air present, and this air can then be calculated from these figures. Hence the importance of air tightness.

Condensers, Electric.—An electric condenser is formed whenever two conductors between which a difference of electric pressure exists, are separated by an insulator, or as it is usual to call it, in this case, a dielectric. A familiar instance of an electric condenser is the Leyden jar, consisting of a hollow glass cylinder closed at one end, and open at the other, having coatings of tin foil on the inside and outside, the open top being closed by a cover of insulating material, to which is attached a rod carrying a brass knob above, and a chain below. The brass knob is used to receive a charge of electricity, and the chain to conduct it to the inner coating of the jar. Another instance is the cable, whether used for telegraph or electric light or power work, that is armoured on the outside. When the outer conductor of a condenser is connected to "earth," and an electric pressure above that of the earth at that point is applied to the inner conductor, charges of static electricity are communicated to the condenser, equal and opposite charges being held on the inner side of each coating of the condenser. When a source of electric pressure is connected to the copper conductor of a cable, equal charges of opposite name are held on the conductor, and on the armour, till the pressure is removed, when the charge on the conductor is poured through it, to both ends. It is this which renders signalling difficult on submarine cables, and that renders telephonic speech through submarine cables impracticable beyond a certain length. Condensers are made for use, by laying sheets of tin foil one above another, separated by sheets of paraffined paper. Leyden jars are used largely in connection with wireless telegraphy, and with certain forms of medical electrical apparatus, such as the high-frequency treatment.

Condensing Engine. (*See also* **Condenser, Air Pump**).—A condensing engine is one which discharges its exhaust steam into a vessel kept as cold as possible, and from which the atmosphere is excluded. Formerly the condenser and its air pump formed an integral part of every condensing steam engine, but in much modern practice any number of engines may exhaust into one common condenser, and the air pump may be equally independent and driven by an engine or an electric motor whose sole duty it is. Modern plant has often been seriously at fault in the very inefficient condensing plant thus supplied, and the auxiliaries of a power station have been so wasteful of steam that the benefits of condensing have been much reduced. The increased mean pressure due to condensing should be 12 to 14 pounds per square inch, according to the temperature and volume of cooling water available. If the mean pressure of a high pressure, or non-condensing engine is 36 pounds, the addition of a condenser should add one-third to the power of the engine, or should enable the same duty to be performed with only so much steam as without condensing would produce a mean forward pressure of about 24 pounds.

Condensing should show large economies where load factors are poor, as in electric traction work, for the mean pressure in the engines averages a low figure, and the constant additional "vacuum" is thus of great relative value, and enables engines of much smaller size to be employed. The steam engine being a heat engine dependent for its efficiency upon the limits of temperature between which it works,

the employment of the condenser adds at once fully 110° to the range of temperature, so that in the basal formula for engine efficiency, namely, $\frac{T_1 - T_0}{T_1}$, where T_1 and T_0 are the absolute initial and final temperatures, their values in the absence of condensation may in a usual case be 820° and 672°, while with condensing they will be 720° and 560°. The above ratio, or the nominal thermodynamic efficiency in the two cases will thus be 0·18, and 0·31 respectively, of which economy a considerable portion will actually be secured.

The temperature in the condenser is usually considerably lower than it should be for the degree of vacuum obtained, owing to the presence of air, and this is one of the reasons why the addition of a condenser does not secure all the economy that might be anticipated.

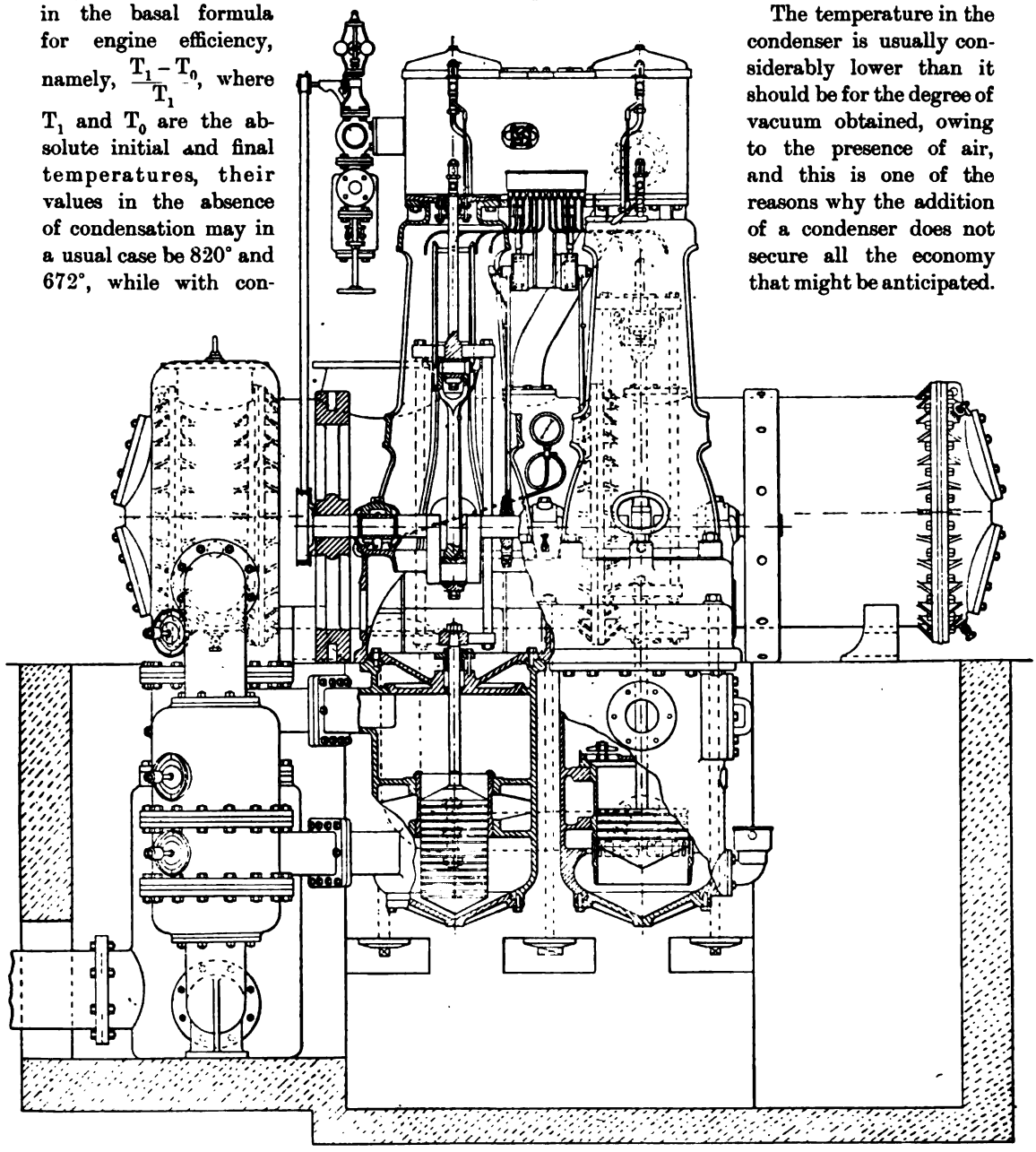


Fig. 49.—Independent Surface Condensing Plant, Steam Driven. Part Sectional Elevation.

Condensing Plant. — This relates to independent machinery for use either with its own steam generator, or for common use with

several sets of engines exhausting into one main pipe. The growing use of **Cooling Towers** for water renders the existence of a large natural supply of cold water no longer necessary. The growth of condensing plants has been quickened by the extension of electricity stations, auxiliary machinery on board ship, and of steam turbines. The saving in steam effected over engines that exhaust into the atmosphere may often be sufficient to avoid the need of extensions to the power plant. Both surface and jet condensers are used for independent plants.

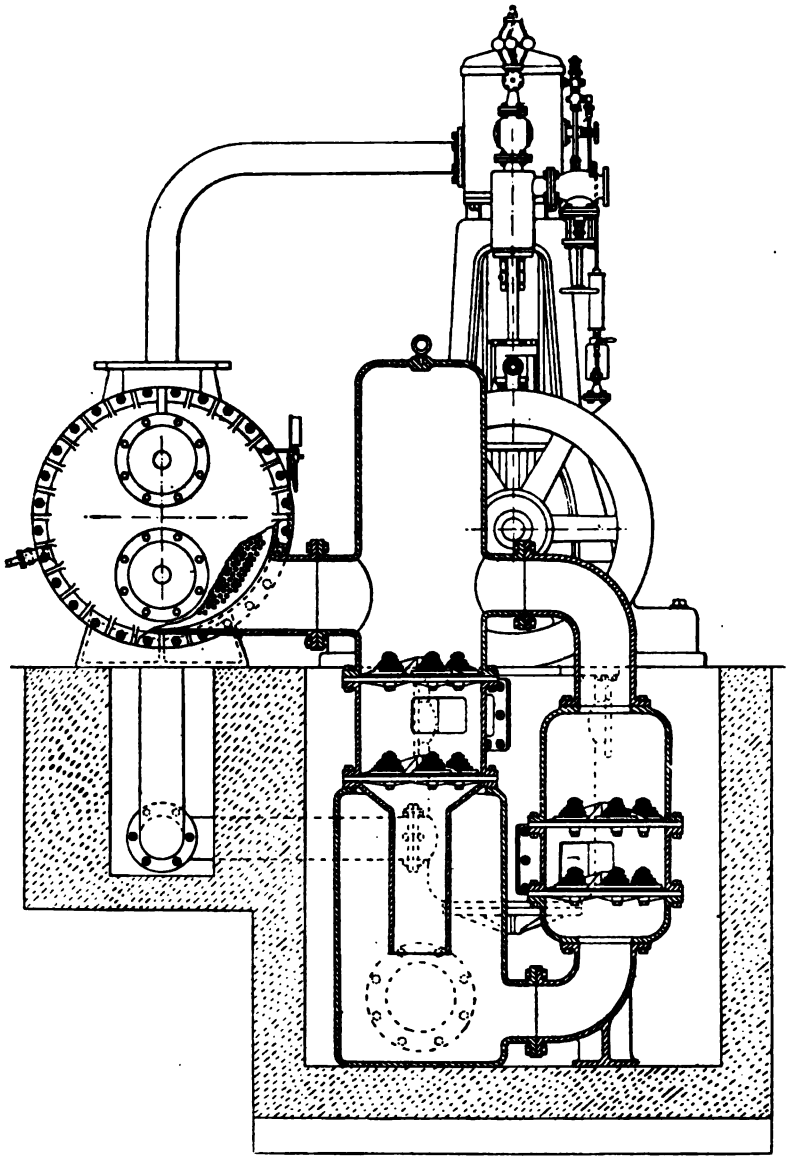


Fig. 50.—Independent Surface Condensing Plant, Steam Driven. Part Sectional End View.

The illustrations are those of two typical condensing plants by Isaac Storey & Sons, Ltd. Figs. 49, 50 represent a surface condensing plant, Fig. 51 a jet type. Around these many variations are made. In the surface condensing types the Edwards' air pump is generally used. The plants are driven by steam, electricity, or other motive power. The circulating pumps are of double-acting reciprocating type. In some cases they are of centrifugal pattern. This plant is steam driven. In a similar outfit, electrically driven, the motor is fixed on a base plate at one end, and is single-geared up to the crank shaft.

Fig. 51 illustrates a type of jet condenser with the Edwards' air pumps. The exhaust steam entering the outer vessel, shown in section, is condensed by cold water coming up through the centre pipe, and thrown down again by the cupped disc through the opening in the disc joint beneath. Here again numerous variations occur. Another type of jet condenser is the horizontal form, in which the pump plunger is driven directly from the steam piston arranged tandem. These have four sets of

valves, suction and delivery, and the jet comes in at the side.

Conductors.—Any portion of the metallic circuit insulated from earth provided for the passing of electricity. Conductors are divided into two classes, cables and bare conductors, the latter being usually referred to as conductors. For the action of cables, *see* **Condensers—Electric.** Thus, whilst the bare wires from which the current for operating travelling cranes, electric cars, locomotives, &c., is collected by trolley wheels or slippers, as also the insulated third rail used in electric railway work would be so described; the earthed rails of tramway systems, although forming a conducting path for the return current, would not be considered as conductors. The metals having the highest conductivity, as copper and iron, are usually employed, although various other metals and alloys, phosphor-bronze, aluminium, &c., have in some circumstances been successfully used.

Cone.—A cone is the figure produced by turning a right-angled triangle round one of the sides containing the right angle, which side remains fixed. The cone A in Fig. 52 may be considered to be produced by the revolution of the right-angled triangle *abc* round the side *ab*. The base *dec* is a circle; *ba* is the axis; *a* is the apex. This is a right circular cone, in contradistinction to an oblique elliptic cone whose axis is not perpendicular to the base, and whose base is an ellipse—a form rarely occurring in practical work. To find the contents of a right circular cone:—

Volume = $\frac{1}{3}$ area of base × height.

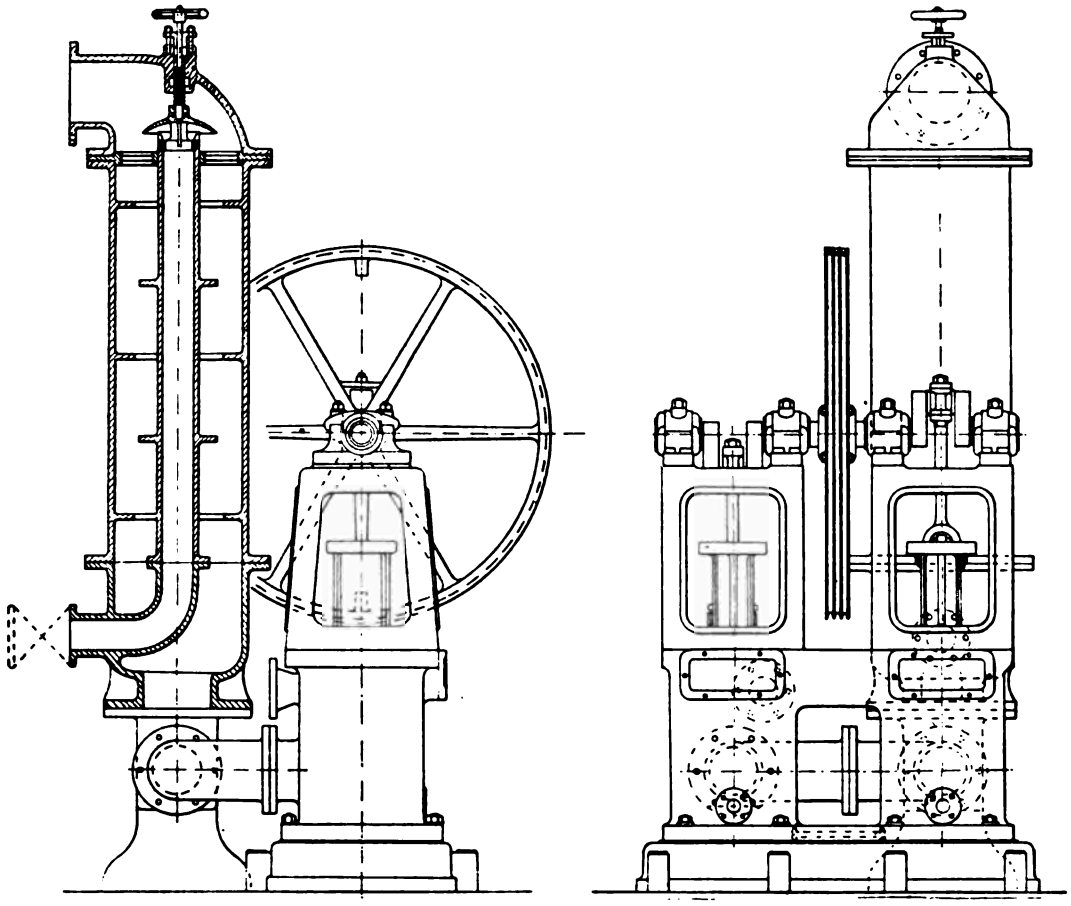


Fig. 51.—Parallel Current Jet Condensing Plant, Rope Driven.

The volume of a cone also =

(*a.*) $\frac{1}{3}$ volume of a cylinder or prism with same area of base and same height.

(*b.*) $\frac{1}{2}$ volume of a hemisphere which has the same base and height.

By transposing the first equation we get—

$$\text{Area of base} = \frac{3 \times \text{volume}}{\text{height}}.$$

$$\text{Height} = \frac{3 \times \text{volume}}{\text{area of base}}.$$

When the circumference, area, or radius of base are given, the area of the curved surface of a cone is found by :—

Area of curved surface = $\frac{1}{2}$ circumference of base × slant height.

Or, area of curved surface = $\frac{\text{area of base}}{\text{radius of base}} \times$ slant height.

The area of the base must of course be added if the entire surface area is required.

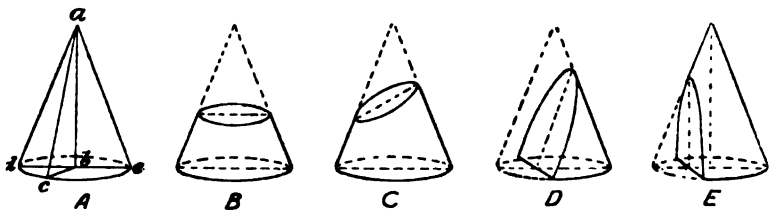


Fig. 52.—Functions of the Cone.

When the top of a cone is cut away in a plane parallel to the base, the remaining portion is called the *frustum* of a cone, and the cone is then said to be *truncated*, B, Fig. 52. To find the volume of a frustum :—

Volume = $\frac{1}{3}$ height × (sum of areas of base and top + $\sqrt{\text{product of areas of base and top}}$).

To find the curved surface of a frustum :—

Curved surface = $\frac{1}{2}$ (sum of circumference of top and base) × slant height.

Areas of top and base must be added to obtain entire surface area.

The series of curves obtained by cutting through the cone in different ways are called *conic sections*, and were studied by the ancient Greeks as far back as B.C. 390.

1. When a right circular cone is cut parallel to the base the section exhibits a **Circle**, B, Fig. 52.

2. When the section is made obliquely without cutting the base the figure obtained is an **Ellipse**, C.

3. When a cone is cut parallel to one of the sloping sides, the section formed is a **Parabola**, D.

4. When the section is parallel with the axis, the figure obtained is an **Hyperbola**, E.

The centre of gravity of a hollow cone lies one-third the way up the line joining the centre of the base and the apex; in a solid cone only one-fourth the distance up this axis.

Cone Bearings.—For many classes of mechanisms the ordinary split bearing is unsuitable, partly because of its tendency to open under severe strain, but chiefly on account of the loss of concentricity which occurs after taking up wear. Thus, when a lathe head bearing is formed with divided brasses, it is most difficult to ensure that the spindle shall always remain at the same height after the lapse of some time, because the act of closing up the brasses throws the spindle downwards. But by employing cone bearings, of circular shape, and split at one or more locations, the closing in takes place all around equally. The method adopted usually is to fit nuts on extensions at each end of the cone, so that it may be drawn along, and locked, from time to time. Very delicate adjustments can be effected thus, the device being therefore suitable to the requirements of high-class lathes, grinding machines, milling machines, &c., where spindles must run freely, yet without any suspicion of shake. Examples need not be illustrated here, as they occur in many of the lathes, grinders, &c., shown in the volumes.

Cone Clutch, or **Cone Coupling.**—A form of clutch that embodies the wedge form in its longitudinal section. The friction of the external and internal cones in contact is sufficient to sustain heavy loads and to drive lengths of shop shafting and machinery. But to a large extent the cone form has been ousted by the **Coil Clutch**, the **Expanding Clutch** group, and other forms. The cone, however, retains its

place as a reversing agent in conjunction with a nest of bevel wheels. Here the double cone on being slid to right or left on its shaft, to which it fits by a feather key, drives one or the other pair of bevel wheels running loosely on the same shaft. The bevel wheel which is engaged drives the crown bevel, so that the direction of rotation of the latter is reversed by the direction of sliding of the cone clutch.

This device is used for light and heavy driving alike. The heavier the duty demanded, the larger must the cones be to afford larger surfaces in contact. The angle of coning must not vary greatly either way from 8° to 10°, or the cones will either not hold securely with excess of taper, or they will seize fast with too little taper.

Such cones are made to fit by turning to templet, and by setting the tool slide to the same angle for turning both portions. Cast iron running against cast iron is best, but steel is sometimes used to get a durable wheel. Then one of the cones must be lined with copper.

Cone Gear, Cones.—The term cone gear is often applied to the cone clutch described above, as it includes bevel wheels in its design. Bevel gears are also cone gears, the *roue conique* of the French engineers, because their elements are conic frustra. The term is also applied to the nest system of spur wheels described under **Change Gears.** The step pulleys of countershafts and machine tools are commonly termed cones, and cone drums. The races of ball bearings are called cones. The cone plays an important part in provision for taking up wear between spindle necks and their bearings. *See* **Cone Bearings.**

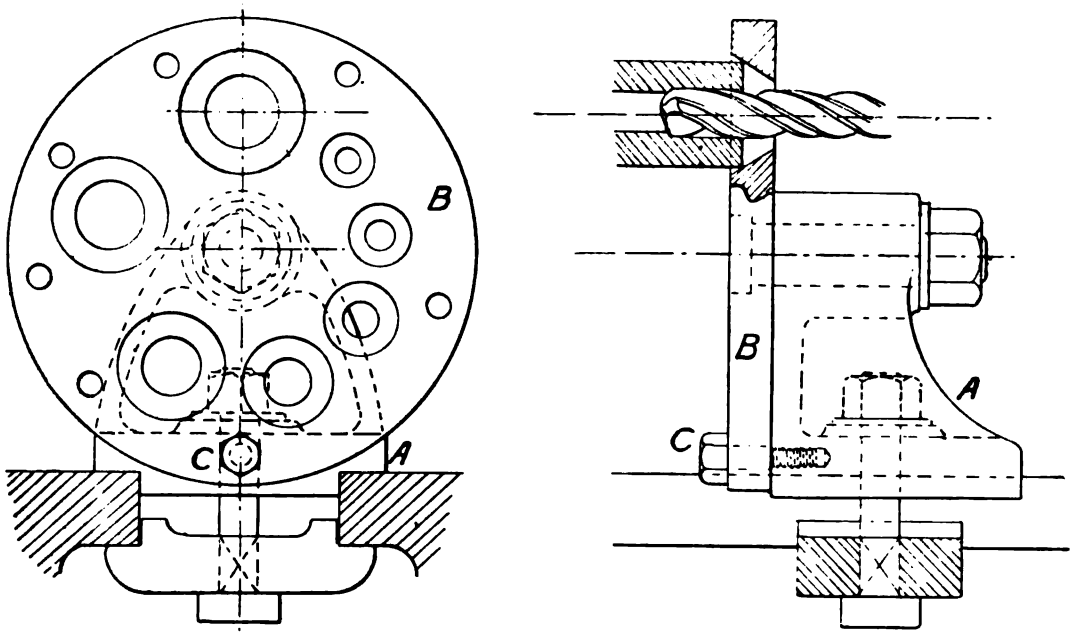


Fig. 53.—Cone Plate.

Cone Plate.—This is a type of steady employed when the end of work has to be bored up. It consists of a casting A, Fig. 53, bolted to the lathe bed, with a disc B, having a number of different sized conical holes, and mounted on a central pin. A set-screw C serves to lock the disc when any one of the coned holes is brought into alignment with the lathe centre axis. The other end of the work, seen running in the hole, is held in the chuck, or driven by a carrier, while the poppet or the slide rest feeds up the drill or other boring tool.

Cone-Vice Coupling.—This is a form of

coupling originally introduced by Sellers, for the ready and accurate union of the ends of shafting. Essentially it is a muff or box coupling having no projecting parts, and consists of three portions—an outer sleeve and two inner split cones, the latter set in reverse relations. The parallel portions of the shafts are embraced by the bored split bushes, which do not meet, and the outer portions of which are turned to conical form, and embraced by the outer sleeve, also bored conically to match. When the cones are drawn towards each other by bolts, the effect of the coning is to cause compression around the shaft by virtue of the splitting. The space between the cones permits of the necessary adjustment. In the coupling modified by the Unbreakable Pulley Company a larger amount of elasticity is secured in the cones by nearly dividing them longitudinally in two places, set in positions of 120° relatively to the split.

Conical Fire-Box.—*See* **Vertical Boiler.**

Conical Stand, or **Conical Mandrel.**—A heavy cast-iron appliance, Fig. 54, used in the boiler shop and smithy for correcting circular rings after they have been bent and welded. Two such rings are indicated in the figure. The tapering form gives a large range of sizes, besides which two or three stands of different dimensions are kept in stock, ranging from about two feet to five feet in height, and diameters in proportion. The slight coning is negligible in shallow rings. The stand simply rests steadily on the floor by its bottom flange. Many mandrels have a slot running down the length, in which may be inserted the end of a bar, being thus held while the bar is bent around by pulling on its other end.

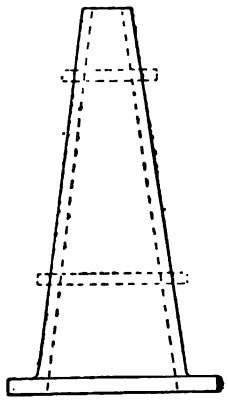


Fig. 54.—Conical Stand.

Conical Tubes, Cone Tubes, or **Galloway Tubes.**—These are fitted in horizontal and vertical land boilers, with a view to increase the circulation. They are particularly valuable in Cornish and Lancashire types to assist in heating the sluggish water below the furnace flue. The water in the lower part of the tube being heated by the hot gases on their way from the furnace to the flues, rises in the flues, so creating a continuous current. They fulfil a similar function in vertical boilers, where they occupy horizontal or else slightly inclined positions, and they also increase heating surface.

The advantages of the conical form are threefold. The bubbles of steam escape better from an end enlarged than they would from a parallel passage. Tubes strengthen the furnace flues. Also the taper is made sufficient in amount to permit of passing the flange on the small end through the hole cut for the large flange, and this determines the amount of taper, except in the case of tubes that are fitted by welding, in which case there are no flanges. Little welding is done now.

Conical tubes are never placed in line, but with their axes at different angles, to give the flame a chance to impinge directly against them. In horizontal boilers the first tube from the bridge is placed vertically, and the succeeding ones at angles of about 30° to right and left from the vertical. See the illustration to **Cornish Boiler.** It is not economical to crowd cone tubes, because they would lower the temperature of the gases, with resulting deposits of soot on the tubes.

The making of conical tubes is work for the angle-iron smith. They are produced by rolling a sheet to the conical form, and welding, followed by flanging. Each process is performed by hand in some shops, by machines in others. The weld is made by the insertion of a glut, welded in short heats. The flanging is done in short heats by hand, or by a rolling process in a machine at one heat. In the shops of Galloways, Ltd., tubes are made up to 4 ft. 6 in. long; up to 2 ft. long the diameters are 8 in. and 4 in. respectively; up to 2 ft. 3 in. long the diameters are 9 in. and 4½ in.; and beyond that length they are 10½ in. and 5½ in. diameter.

Marking out.—Draw a circle, Fig. 55, of the diameter of the furnace tube, and within it outline the conical tube A B C D, completing the lines to the apex *o*. Strike a half circle E E, and divide it into any convenient number of equal parts

a b c d e f g. Draw lines from the apex *o* through these points of division to cut the circle of the furnace at 1 2 3 4 5 6 7, and 1′ 2′ 3′ 4′ 5′ 6′ 7′. From the points of intersection of these with the circle draw horizontals, lettered as shown, to intersect the prolonged slant edges *o* A, *o* B.

The development is shown in the figure adjacent to the right. Arcs are struck from *o*, *o* A B, and *o* C D, corresponding with the distances taken on the slant in the previous figure. At equal distances from the centre line *o o*′ set off the length A B equal to the circumference of A B in the previous figure. Divide A o′ o′ B each into the same number of equal parts as the half cone in the figure adjacent, and prolong these lines to *o*, cutting C D as shown.

As the lengths for development must be taken along the slant heights of the cone, the positions 1 2 3 4, &c., have to be prolonged until they intersect the slant line *o* B *o* D. These then have to be measured off one by one from *o* to the intersections, and then transferred from *o* to the corresponding lines in the development. These are shown clearly by the identical references. The curves drawn through the points of intersection will give the outlines of the tube only. Lines F F, G G must be drawn beyond these for the flanges, to which the plate must be cut. Then when bent to a circle and welded, the ends will be right for flanging to fit the furnace.

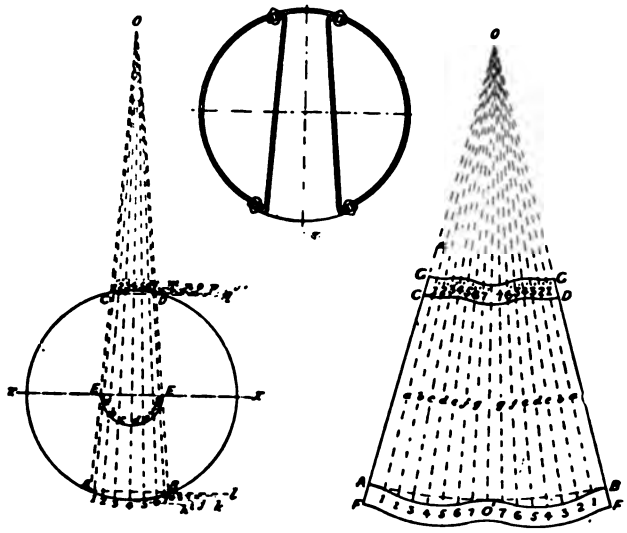


Fig. 55.—Development of Conical Tubes.

Conical Turning.—*See* **Taper Turning**.

Conic Sections are the curves obtained by cutting a right circular cone in certain directions. *See* **Cone**.

Connecting Rod.—One might fill many pages with a study in connecting rods, so varied are their details. In any rod the wear on the crosshead end, the *little end*, or that corresponding with the centre of the slipper block is very slight, the rod pivoting through a few degrees of arc only there. But the wear at the crank end is severe, hence the numerous provisions for taking up slack. With increase in dimensions the details of the design generally increase.

A very simple form of *little end*, and one that has done much service in the older engines, is that in which the piston rod passes beyond the pin which unites it to the connecting rod, to move through a bushed bridge form of guide. The connecting rod clears this guide by its forked shape, and the pillars of the bridge guide are set sufficiently far apart to clear the forks.

In the ordinary type with slipper block, the end of the rod fits between the crosshead, cottered on the end of the piston rod. There may, or may not be provision for taking up wear by a gib and cotter. Fig. 56 shows a method of take-up. If no such provision is made the bore may not even be bushed with brass.

In many cases the little end fits outside the crosshead with a small amount of forking, or just enough for clearance. Then the crosshead is frequently fitted as a bearing with a cap and pair of brasses, to take up the slight amount of wear that occurs in time.

It is, however, at the *big end* that the greatest variations in types are found.

The simplest design here is that termed the marine pattern, Fig. 56, which comprises practically two cap-like halves bolted to a flat end forged on the rod. Wear is taken up by removing a little from the joint face. Adjust-

ment for centres is effected at the little end by the cotter bolt and brasses.

A more complete rod is that in which adjust-

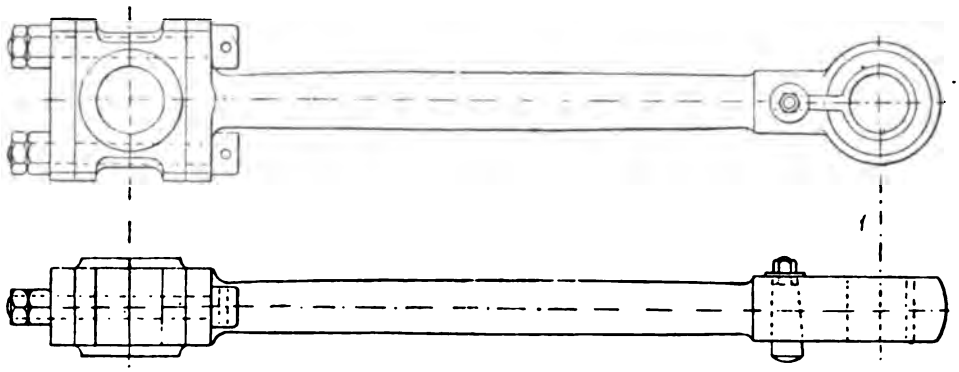


Fig. 56.—Marine Pattern Connecting Rod.

ments are made at the big end by means of a strap, gib, and cotter, and round this the changes are rung in many diverse forms. In Fig. 57 the strap is pulled up against the outside brass by the tightening of the cotter, so shortening the centres. The centres can be

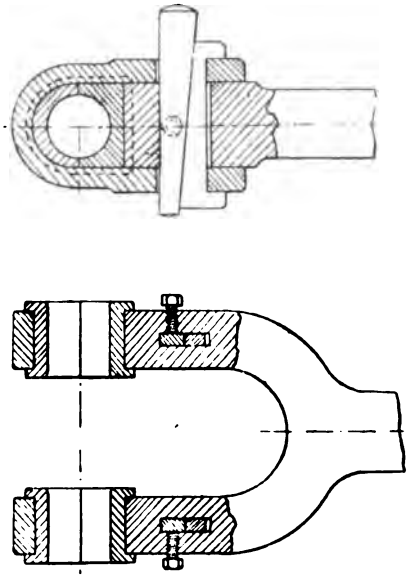


Fig. 57.—Big End with Single Gib.

lengthened by inserting packing between the square brass and the stub end. The gib prevents the strap from opening out. The cotter, or key is prevented from slackening back by the set-screw shown. The gib and cotter is used in forked ends as shown, as in those which are not forked.

In a modified form, Fig. 58, two gibs are used, giving a more solid job, the strap being embraced on both sides of the cotter, and the latter takes a bearing all down the edges of both.

There are many big ends in which the straps do not slide on the stub end, but are bolted thereto, Fig. 59. The tapered cotter, still retained, is then made to drive against the brasses. In another design, Fig. 60, the big end is solid, with a portion slotted to receive

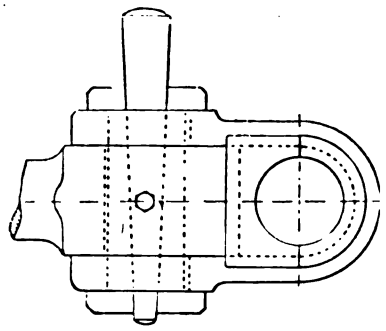


Fig. 58.—Big End with Two Gibs.

the brasses. The bottom brass has its stub end face bevelled, and a wedge block fits against this, and is tightened against it by a bolt, the thread of which fits a tapped hole in the block. A better plan is to have two set bolts,—see Fig. 61, which combines the features of Figs. 59 and 60.

The amount of angularity or obliquity of the connecting rod is dependent on its length, and this affects the position of the crankpin at mid-stroke, and also the intensity of the pressure on the guide-bars. For these reasons connecting rods are properly made of good length, from $2\frac{1}{2}$ to $3\frac{1}{2}$ times that of the piston rod.

However long a rod may be, the crankpin is never situated perpendicularly in regard to the crankshaft when the piston is at mid-stroke, but is always inclined towards the cylinder. Conversely when the axis of the crankpin is perpendicular to the crankshaft the piston is not exactly in the middle of its stroke.

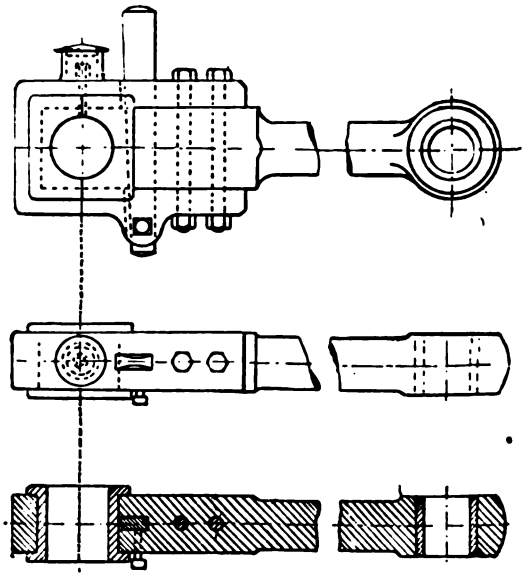


Fig. 59.—Big End with Fixed Strap.

As the piston and crosshead both always occupy the same relative positions to the crankpin, the crosshead is conveniently taken in making diagrams of the relative velocities of connecting rod and piston.

The rate of revolution of the crankpin is practically uniform, that of the linear movement piston and crosshead varies constantly. At the ends of the stroke it is for an instant stationary. When the crankpin is at its central position, that is, at right angles to the direction of the motion of the piston, the velocities of the piston and crankpin are equal. At two points just before these in the rotation, the velocity of the piston is greater than that of the crankpin. The subject is one that lends itself to interesting analytical treatment, as a study in link work,

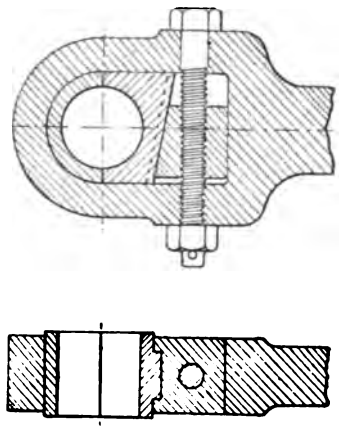


Fig. 60.—Solid Big End.

for which Professor Kennedy's "Mechanics of Machinery" may be consulted.

Conservation of Energy.—Postulates the fact that energy cannot be destroyed, in other words, "The sum of all the energies in the universe is constant." Energy, if it ceases to be manifest in one form, appears in another. Work, friction, heat, electricity, and other forms are manifestations of energy in various guises. That energy cannot be created is the one unanswerable argument to the dream of perpetual motion, and is an ever-present memoritor to the engineer. The subject is most fascinating, but we can only here state the broad divisions of energy. These are, that of visible motion, that of position, that of heat

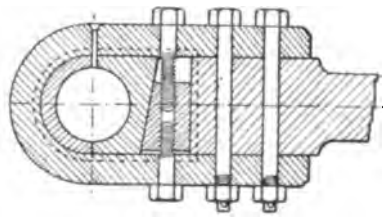


Fig. 61.—Big End with Fixed Strap and Wedge Block.

movements, of molecular separation, of chemical or atomic separation, of electrical attraction and repulsion and motion, and radiant energy.

All energy in the vast universe is in a state of constant transmutation. Much of the work of the engineer consists in suppressing some forms, and developing others; coercing the changeless forces to do his will.

Constant.—A fixed quantity which enters into given calculations, and does not vary throughout an investigation; generally it is either an empirical number, or one deduced from experiments. Constants are employed in column calculations in the Gordon and other formulæ; like those used in beam calculations, they are derived from experiments. Empirical constants are frequently definite figures added to the result of working out a general rule for the proportion of a mechanical or structural detail. The constant may be either prefixed or affixed in order to produce a satisfactory final proportion.

Constant Travel.—The travel of a slide-valve which is uniform, being derived directly from the eccentric instead of through link motion, or by back cut-off valves.

Continuous Beam.—*See* **Beam.**

Continuous Current.—*See* **Alternating Currents, Dynamo.**

Continuous Lubrication.—The difference between the older and the modern methods of lubrication lies chiefly in the continuous character of the latter. Instead of pouring oil from a can at frequent intervals through oil-holes, the lubricant is contained in reservoirs or tanks with provision for automatic feeding by gravity; or for constant feed under pressure by means of pumps, or by capillary movements. These devices are applied to motors of all kinds, and to machine tools.

Continuous Mill.—A mill for rolling billets, wire rods, and light sections of merchant bars and angles in lengths of about 300 feet and upwards, and which is vastly more economical than its rival the old Belgian mill. It has been developed by Mr C. H. Morgan, and is in use in several steel works in the United States. The rolled product is ready for use; or in the case of merchant sections, finish is imparted in another set of rolls. These continuous rolls would not have proved successful, but for the fact of the development of the **Flying Shear**, which cuts off the bars, &c., while they are passing rapidly through the rolls. In the billet mill, from six to twelve pairs of rolls are placed tandem. Between each pair, twist guides turn the advancing steel through an angle of 90°. The most remarkable feature is that the speed of travel is increased in each succeeding pair of rolls, by so proportioning the driving bevel gears. Thus, a billet that enters a mill at a slow speed, leaves the last pass, 600 to 1,000 feet long, running with a velocity of 500 feet and upwards per minute. This remarkable increase in speed has two excellent results. The quality of the billet is rendered much more uniform than in the Belgian mill, because the work done on it is so great that nearly uniform temperature is maintained; the result is a soft quality throughout, instead of a variable product at opposite ends where the length is limited by rapid cooling, as in the Belgian mill. And in the continuous system there is no limit practically to the length that can be rolled.

The wire rod mills and the merchant mills for merchant bars are special applications of the foregoing. Each, too, requires round it its own auxiliary plant, including continuous gas-heating furnaces, gas producers, flying shears, laying reels, and wire truck loaders for the wire rod mills; cooling beds, bundling and storage arrangements for merchant bars; and steam and electric plant, &c.

One economical result is destined to hit the older plant hardly, and that is the delivery of odd sizes of bars from stock. The bars can not only be produced at little more than half the cost, but stocks are kept in hand, and any odd lengths are cut off to order by an electrically-driven travelling shear, located in the storage building.

These continuous mills are costly, but they prove good investments, due to their enormous output, the small expense for labour, and the excellence of the product. A few figures only can be given here as to the output of these mills.

A billet mill of nine stands of rolls will reduce from 900 to 1,800 tons of 4-in. by 6-in. blooms into-1½ in. billets in twenty-four hours. The number of men is ten per shift, and only the roller and the engine-driver need be trained men. The cost of such a mill may range from £25,000 to £50,000.

A continuous wire rod mill has an average capacity of 160 tons of No. 5 rods per twenty-four hours, running one rod at a time. At the Sharon Steel Co.'s works, two continuous rod mills, placed side by side, can produce over 500 tons of rods per day. When the rods leave the mill, they are travelling at a rate of about 2,000 feet per minute. The cost of a rod mill plant may vary from £30,000 to £40,000.

A 10-inch merchant mill at the Duquesne Works of the Carnegie Steel Co., rolled in January of 1903, in twenty-four hours, 433 gross tons of $\frac{3}{4}$-in. round rivet bars. The capacity of a 13-inch mill at the same works is from 400 to 600 tons per twenty-four hours.

Continuous Moulding. — Relates to a minutely sub-divided system which is carried out in the manufacture of specialities. Chair moulding is a case in point, in which casting goes on all day long, and the cupolas constantly are running at the tap hole. In the more modern installations, conveying systems are included for the transit of sand, moulds, and finished castings. Moulds are then frequently made on separate sets of machines, the top and the bottom by different men, the cores by another set of hands. Cores are set by other men, the boxes are closed by another, poured by another gang, and finally knocked out for the fettlers to take in hand.

Continuous Open-Hearth Process.—*See* **Talbot Process.**

Contraction of Area.—When a bar is elongated by tensile stress, its area is at the same time reduced. It is usual to state the contraction of area at the moment of rupture, and the amount of this must always be regarded in estimating the ductility of a specimen in conjunction with its strength. The breaking strength may obviously be estimated on the original section of the bar, at so much per square inch.

Contraction Rule, or **Shrink Rule.**—A rule used by pattern-makers. It is slightly longer than the standard rule, and so saves the pattern-maker the trouble of calculating how much to allow for shrinkage. For iron contraction, the rule is usually longer than the standard by an $\frac{1}{8}$ in. in 15 in., and for brass and steel $\frac{1}{8}$ in. in 10 in., but this amount cannot be taken as absolutely correct for all kinds of iron, brass, and steel, and under all circumstances. It is merely considered near enough for most work, and has sometimes to be departed from. A common practice in America is to work with a standard rule and allow an $\frac{1}{8}$ in. to the foot on large iron castings, and nothing at all on dimensions of only a few inches. Except that this slight amount is added to its length the contraction rule does not differ in any way from a standard rule.

Controller.—A form of starting switch for electric motors, specially constructed to control or to regulate their speed. A common form of controller is that used for electric tram cars; it is of the drum type, and has its resistances on separate frames, Figs. 62 and 63, Plate III. It consists essentially of a vertical drum upon the surface of which are arranged contact pieces so placed as to engage with fixed brushes carried on the controller frame; the main leads and the resistances are connected to these brushes in such a way as to have the whole of the resistance in circuit when starting. As the handle is gradually moved round, the various contact pieces come into contact with their relative brushes, and the resistance is cut out of circuit, until on the last step it is short circuited altogether, and the motor receives the full voltage.

When trams are fitted with two motors, the controller is arranged with two main working positions apart from the intermediate regulating steps; the first working position places the motors in series; when after all resistance is cut out, each motor naturally obtains half voltage; the second position places them in parallel, where they each obtain full voltage. The first position is used when starting from rest, or when ascending heavy gradients, the torque being then at its maximum; the full speed is attained when in the second position. A small auxiliary switch is fitted for the reversing of the direction of the current; it is mechanically interlocked with the controller handle, so that the motor cannot be reversed unless the handle is in the "off" position. Braking contacts are sometimes fitted, whereby in certain positions of the handle, the motor is short circuited through the resistance, and runs as a

dynamo driven by the impetus of the car. A magnetic blow-out is invariably fitted to the tramway type of controller.

This form of controller has wide applications apart from tram car service, and consequently has many variations of construction. They are made to control either series, shunt, or compound wound motors. As applied to machine tools they displace back gears and speed cones, as many as forty different speeds being obtainable with one controller, the principle adopted being double voltage, and shunt regulation of the motor.

For crane service two controllers are frequently coupled to a single handle by means of bevel gears or universal couplings. The two motors thus controlled are usually those for hoisting and slewing; and the controller lever is arranged to move in the same sense as the movement it controls. In many forms of hoisting machinery it is desirable to have the resistance arranged as part and parcel of the controller, thus making it a complete self-contained unit. A well-tried and successful form is the Dinkey ventilated controller, shown in Figs. 64 and 65, Plate IV. It is of substantial mechanical construction, well suited for rough handling; it has no separate reversing switch, but is in the "off" position when the lever is central, reversal being obtained by moving the lever either forward or backward: it is thoroughly ventilated, and is accessible for examination or renewals. Fig. 66, Plate IV., illustrates a face controller, designed specially for the Wellman charging machines.

Another type of controller in use for tools and cranes is that which has its resistance in liquid form, Fig. 67, Plate IV. The base of the controller is a tank which contains a solution of soda; contact is made by curved dipped plates which enter the liquid; when all resistance is cut out, metallic contact takes place.

This is largely installed in steel works and shipyards, where it has proved reliable and durable under conditions of rough usage and dirty surroundings. The contact rings and reversing switch are enclosed in a dust-proof casing immediately under the hand-wheel. They are mounted on a slate box supported from the tang by brackets; the dipper plate is raised and lowered by means of a rod and roller engaging in the curved grooves of a right and left hand cam frame. Reversing is effected by moving the hand-wheel either to right or left. The resistance is varied by altering the density of the solution and the shape of the curved dipper plate; contact is made and broken on the surface of the liquid, consequently there is no necessity for a blow-out, and there are no contacts liable to be injured by sparking.

Converted Bars.—Bars of malleable iron converted into blister steel by the absorption of carbon at a high temperature. *See* **Cementation.**

Converter.—*See* **Bessemer Converter.**

Conveyor Belt.—*See* **Belt Conveyor.**

Conveyors, or **Conveying Machinery.**—The term signifies that group of transporting mechanisms in which the material is carried in a horizontal direction or approximately so. It includes the following types: belt or band, screw, cable, or chain, and trough conveyors. They fill a large and growing place in modern transport, superseding hand barrows. There is no material, from seeds and grain to masses of iron and steel, and solids and liquids that cannot be handled with conveyors of some type or another. Examples of these will be found under various heads.

Cooling Towers, or **Water Cooling Towers.**—The cooling tower, Fig. 68, is a contrivance for bringing rapidly into contact with large volumes of air the heated circulating water of a condensing plant, whereby heat is carried off within a small space. Cooling towers are filled with galvanised wire mats, thin short lengths of steel or earthenware pipes placed on end, or with thin boards. Board coolers are often built open, so that the wind plays through them freely, the water to be cooled descending the thin boards and being brought into contact over a great surface with the wind currents.

Enclosed type towers are usually fitted with a chimney top, Fig. 68, so as to produce an up-draught of air. Other towers have air blown into them at the base by means of fans.

In all, the principle is the same, namely, the carrying off of heat which is rendered latent by the absorption of some of the water in the stream by air which escapes saturated and hot



Fig. 64.—Dinkey Ventilated Controller. Front view.

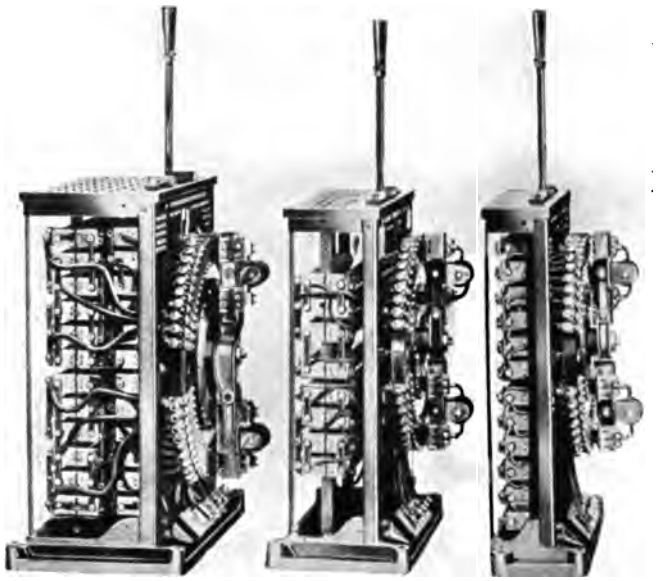


Fig. 65.—Comparative Sizes of Dinkey Controllers. Side views.
(The Wellman-Seaver-Morgan Co., Ltd.)

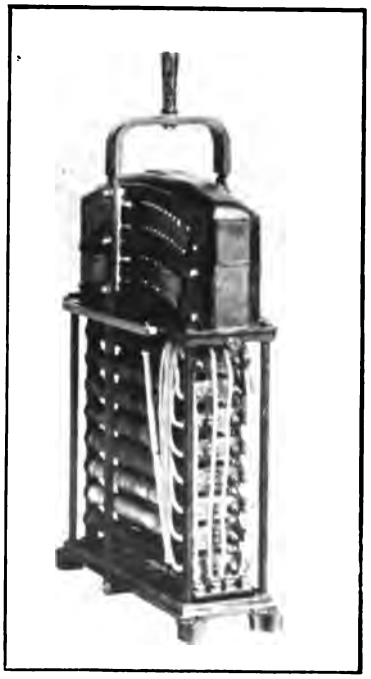


Fig. 66.—Vertical Face Controller.
(Wellman-Seaver-Morgan Co., Ltd.)

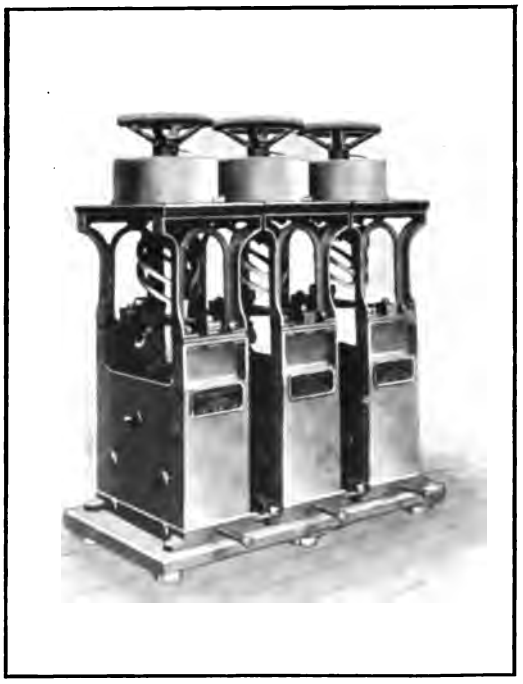


Fig. 67.—Liquid-Type Controller.
(Steel, Peech, & Tozer, Ltd.)

To face page 68.

at the top of the tower where the hot water enters. Air at 104° Fahr. will carry 4·84 per cent. of its own weight of water. At 59° Fahr. air is saturated with 1·05 per cent. only. It is therefore possible under ordinary conditions to carry off 3·84 lb. of water for each 100 lb. of air. Indeed, a capacity of 5 per cent. may be ordinarily calculated upon, for the entering air is rarely saturated and the top temperature usually exceeds 104° Fahr., above which the absorption increases rapidly. The writer's figure for air supply is 300 cubic feet of air for each pound of feed water, or practically the weight of air will be about the weight of the circulating water. About 5,000 B.Th.U. may be carried off by each 1,300 cubic feet or 100 lb. of air. Towers are of course less efficient in moist weather or fogs, but fogs usually occur in cold weather, and, even if fully saturated at 50° Fahr., air only carries 0·765 per cent. of moisture, and at 113° Fahr. it carries 6·45 per cent., so that there remains over 5 per cent. absorption possible. The warming of the fog-laden air from 50° to 59° would make it only pleasantly dry. It is the added temperature acquired from the water which enables the air to carry off water and heat. With open board coolers 20,000 gallons per hour may be cooled in a space 40 ft. × 20 ft. × 13 ft. high.

In a chimney cooler 2,000 gallons per hour may be cooled on a floor space of 8 ft. × 8 ft. × 46 ft. total chimney height; and 20,000 gallons on a space 19 ft. × 19 ft. × 57 ft. high. With fan draught coolers, a space of 11 ft. × 13 ft. is sufficient for 20,000 gallons per hour, and about 5 brake horse-power will be absorbed by the fans. Water may always be thus artificially cooled with a loss of weight of about three-fourths that of the steam producing the heat carried off. As a further economy of steam is possible from the addition of a condenser to an engine it follows that a condensing plant with water cooling towers will require less water than a non-condensing plant, and therefore there is no logic in the excuse that "condensing is not employed for lack of circulating water." Care should be taken to place cooling towers at some considerable distance

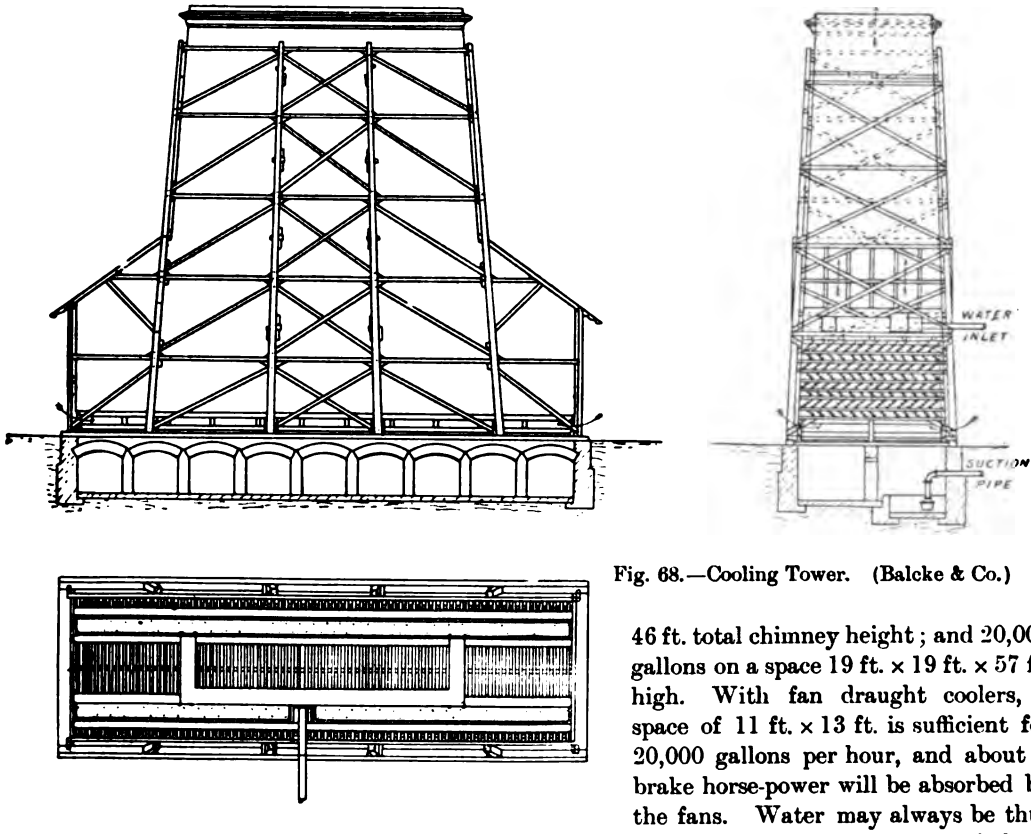


Fig. 68.—Cooling Tower. (Balcke & Co.)

from important buildings, and to the lee side of them, for the constant outpour of steam and wet air is destructive of brick-work and injurious to machinery, especially to electrical work, the insulation of which should not be exposed to damp.

Cope.—The upper part of a foundry mould, more often applied to loam than to green sand.

Copper (Cu. C. wt. 63·6).—This metal ranks high in value in engineering. It was known and used in the earliest times as shown by the discovery of prehistoric weapons of copper. A copper knife was brought up from a boring in the valley of the Nile, 24 feet deep, and at the normal rate of deposit this depth would imply an antiquity of some 10,000 years. The age of copper probably followed the Stone Age, and preceded the Bronze Age.

Copper possesses a characteristic red colour, is very ductile, malleable, and extremely tenacious; it is an excellent conductor of heat and electricity; dissolves in hot strong sulphuric acid, and also in nitric and hydrochloric acids; it oxidises only at a red heat. Sp. gr. 8·9. Pure copper is not suitable for castings, as when melted it absorbs gases which escape when the metal cools, leaving it porous. It is therefore mostly used in the form of sheeting, tubing, and wire.

This metal is found native about Lake Superior, and in Australia, but is mostly obtained from its numerous ores, the chief of which is the sulphide of copper and iron, $CuFeS_2$, called copper pyrites or yellow copper ore. Other and richer ores are cuprite, the red oxide of copper, Cu_2O (nearly 90 per cent. pure copper); black oxide from Chili, and malachite, the green carbonate of copper, $CuCO_3$, $Cu(OH)_2$ (nearly 57 per cent).

The pure metal is easily obtained from the oxide or carbonate by heating with coke or charcoal in a blast furnace, when the following reaction takes place:—$Cu_2O + C = 2Cu + CO$. Its preparation from copper pyrites is a longer and more difficult process, involving a series of six successive operations, or more, in reverberatory furnaces. The ore is first heated for some twelve hours, and the sulphides of copper and iron are partially oxidised, sulphurous acid being given off. The roasted ore is then melted with a silicious slag, and the oxide of copper formed in the previous stage becomes in the succeeding stages converted into a sulphide; and the sulphide of iron still present becomes an oxide of iron which unites with the silica, and is removed in a light slag. The sulphide of copper, or "coarse metal" as it is called, still contains a considerable percentage of ferrous sulphide. It is therefore again fused with slags containing a large proportion of oxide of copper, so that the remaining sulphide of iron becomes oxidised, leaving the "fine" or "white" metal containing about 75 per cent. of pure copper. The fine metal is next roasted, with the formation of cuprous oxide, which acts on the sulphide, and forms copper, and sulphur dioxide: $Cu_2S + 2CuO = SO_2 + 4Cu$. Finally this still impure metallic "blister" copper is refined by melting in contact with air for 15 to 20 hours, anthracite being thrown on the surface of the mass to reduce the oxides formed, and at the same time the molten metal is "poled," *i.e.*, stirred with long poles of green birch or oak. That, in brief, is the process in use at Swansea. Smaller quantities are also obtained by what is known as the Wet Method of Extraction. In this process the residues obtained in burning sulphide of iron or iron pyrites (for the manufacture of sulphuric acid), are mixed with salt and heated. The copper then becomes converted into a soluble chloride which is dissolved out, and the metal, thrown down by scrap iron.

As regards its compounds, copper forms two oxides, cuprous oxide, Cu_2O (used for colouring glass a ruby red), and cupric oxide, CuO (colours glass pale green), and corresponding cuprous and cupric salts. Cuprous chloride, Cu_2Cl_2, is valuable chiefly owing to its property of absorbing carbonic oxide gas; cuprous sulphide, Cu_2S, occurs native as "copper glance." The chief cupric salts are cupric sulphate (blue vitriol, sulphate of copper), $CuSO_4$, $5H_2O$, used in dyeing and calico printing; cupric nitrate, $Cu(NO_3)_2$; cupric sulphide, CuS; cupric chloride, $CuCl_2$, $2H_2O$; cupric arsenite, $CuHAsO_3$, known as Scheele's green; and some cupric carbonates. Cuprous compounds are mostly colourless, but solutions of cupric salts are blue or green.

Copper is used almost exclusively for the fire-

boxes of locomotives, and for electrical transmission and in dynamo construction, and electrical machinery generally.

The copper alloys are of great value and importance, and are dealt with under their names. *See* **Aluminium Bronze, Bearing Metals, Bell Metal, Brass, Britannia Metal, Bronze, German Silver, Gun-Metal, Manganese Bronze, Muntz Metal, Speculum Metal, Yellow Metal.**

Copperas.—Ferrous sulphate, $FeSO_4, 7H_2O$, also called green vitriol, and protosulphate of iron. It is prepared by dissolving iron in sulphuric acid, $Fe + H_2SO_4 = FeSO_4 + H_2$; or by the oxidation of iron pyrites in the presence of moisture. Copperas is used in the manufacture of writing ink, and of black dyes.

Copper Bit, or **Soldering Iron.**—The prismatic piece of copper on a handled rod used in melting and controlling the soft solder for joint making.

Copper Casting.—Copper castings are not generally satisfactory, because they develop wholesale sponginess. To prevent or lessen this the metal must be fluxed. The reason why sound castings of pure copper cannot be made is that the metal occludes gases which render it spongy.

Many devices have been proposed and adopted to render castings sound, but it is obvious that only small quantities can be dealt with if the approximate purity of the copper is to be retained. Zinc figures largely, and answers well, to which a little phosphorus can be added with advantage. Half an oz. of zinc to the lb. of copper is a suitable proportion for producing sound castings. Often it is added as brass, 4 oz. of brass to 1 lb. or 2 lb. of copper.

Copper Hammer.—A hammer of copper, used instead of a steel one, for striking bright work, without risk of causing bruises.

Coppersmithing.—This work is an important department of some branches of engineering practice. In marine work large quantities of copper pipe have to be bent and brazed, though seamless pipes are largely used: in locomotive work copper is used in fire-boxes. In brewers' engineering, copper vessels have to be hammered, bent, brazed, and pipes bent, and flanged. The work has been invaded but slightly by machinery. Raising and flanging are mostly done by the hammer, joints are cramped, and brazed pipes are bent by templets. Sheet copper is worked into all conceivable forms by hammer and press, brazed and riveted; engineers' coppersmith's work involves little more than this. The tools used include stakes and hammers in numerous forms and dimensions, mandrels, chisels, shears, punches, compasses, squares. Some of the principal work of engineers' coppersmithing will be found noted under other heads. Fig. 69, Plate V., illustrates a large workshop.

Copying Lathe, or **Blanchard Lathe.**—So named after its inventor, is used for profile turning with the help of a copy or former. Fig. 70, Plate V., shows a typical design, employed for producing rifle stocks, and spokes and handles of all kinds. The head carries two spindles, one driving the steel copy, the other the work (seen to the front in the photo). A coned bearing supports the outer end of the copy, and a special ring type the end of the work, unless it is plain, like a hammer handle, when an ordinary centre is suitable. Two swing frames, one holding a former roller, the other the cutter head, with a ring of six cutters, are connected, so that as the copy roller is moved to and fro by the coercion of the copy, the cutter head is compelled to travel to and fro similarly, nibbling away the wood of the rough stock to finished shape. Longitudinal motion is self-acting, and the driving belt is actuated from a splined shaft (seen under the bed), on which the cutter-head frame pivots, the pulley on this shaft travelling with the frame, and so driving at any point. An article up to 3 ft. 6 in. by 8 in. diameter can be cut.

Cordite.—The smokeless explosive used in the British Army and Navy, and so named from its cord-like appearance. It is a mixture of 58 per cent. nitro-glycerine; 37 per cent. gun cotton; and 5 per cent. mineral jelly—vaseline. These three constituents are mixed in a machine by revolving blades for seven hours. The thick paste—"cordite dough"—is then forced through plates containing holes of different diameters (varying from ·01 in. to ·5 in.) according to the gun in which it is intended

to be used. The threads of small diameter are wound on to reels as they issue from the hole; those of larger diameter are automatically cut into lengths. The cordite is finally dried in a room having a temperature of about 105° Fahr.

Cordite is of a light buff colour; sp. gr. = 1·56; burns harmlessly when lighted, but explodes when detonated by a fulminant; is unaffected by damp.

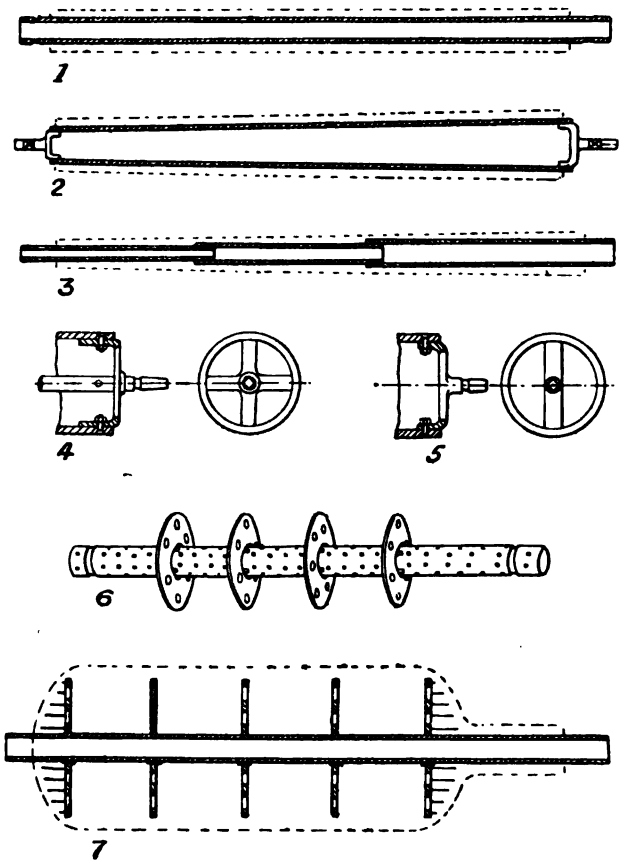


Fig. 71.—Core Bars and Plates.

Core.—Besides the special articles following the term core is prefixed to others, thus:—A core barrel is a core bar of large diameter. A core bench is an iron bench on which the smaller cores are made; a core board is one against the profiled edge of which a core is swept up, so avoiding the making of a box. A core boy is one who makes the small stock cores; a core carriage is a low iron carriage that is run into the core stove; core irons or core rods are rods straight or bent, used as the skeletons of cores. A core ring is an iron ring used in loam work; core sand is a strong sand.

Core Bars—Core Plates.—The core bars form a considerable portion of the stock-in-trade of a founder. They are either made of gas piping in the smaller sizes, or are cast-iron cylinders in the larger, or they are special bars of the collapsible type. The gas pipe employed for the smallest core bars is often as small as $\frac{1}{4}$ in. or $\frac{3}{8}$ in. diam.

The function of a core bar is to afford rigidity to the loam, and to allow the gas which is generated in the core free exit through the bar to the outer air. As therefore the core bar performs the same function to the core that the vent holes do to the mould, it is pierced with numerous small holes, which convey the gas from the exterior on which the core is swept, to the interior which communicates with the outer air at the ends, where the bar passes through the ends of the box.

Bars of gas pipe, Fig. 71, (1), with drilled air holes, are used for cores up to about 3 in. diameter, above which bars of cast iron are employed. These are simply plain cylinders cored out, parallel, or tapered (2) as for columns, and pierced with small cored or drilled vent holes. They are made up to 10 in. or 12 in. diameter. Their thickness depends upon their length, the longer bars having the thicker metal to afford stiffness. As in moulding boxes, this rigidity is essential, so that, dependent on size, cast-iron bars may range from $\frac{3}{8}$ in. to $1\frac{1}{2}$ in. thickness. Rigidity is necessary, because if a core bar springs, it is not only difficult to sweep up the core truly, but there is much risk, when in the mould, of the bar rising in consequence of the pressure of the metal, so causing unequal thicknesses in top and bottom. Another danger is lest the core should crack in bending, and admit metal to the interior, causing a blown casting.

When tapering core bars are required they are

either cast of that form, as when large (2), and of cast iron; or if small, and of gas pipe, short bars of different diameters are wedged one within the other, with wrought-iron wedges (3). Some recent bars are grooved longitudinally.

It is necessary that core bars shall run truly. Hence, whether of gas pipe, or of cast iron, grooves should properly be turned round their circumference near the ends to run in the vees of the trestles. An ordinary winch handle is used for turning the bars, being inserted into one end, and turned by a boy. In the case of the small gas piping, the axis of the handle is simply formed square at the end, and being inserted at the end of the bar is retained firmly with iron wedges or nails alone. In the cast-iron bars a special trunnion piece is made and inserted into the end, and the handle is finished with a square recess to embrace a corresponding square end on the trunnion. Fig. 71, (4) and (5), shows two forms made in cast iron, and suitable for the longer bars, and for bars of moderate dimensions.

When large core bars are wanted for jobbing work, the diameter is made up with core plates.

Core Plates.—These denote two different kinds of articles, the plates which are used on core bars, and those on which loam moulds are built.

Fig. 71, (6) and (7), represents cast-iron core bars and plates. These in many cases have to be broken up with a sledge and a bar, before the core can be extracted; and are therefore cast as thin as possible consistently with strength. Thus a plate 16 in. or 18 in. in diameter would not be more than $\frac{1}{2}$ in. or $\frac{5}{8}$ in. in thickness. The plates are wedged on the bar, and the holes cast in assist their fracture. The space between the plates is filled with hay bands wound round. These plates when of large diameter are held together and stiffened with bolts passing through them, a necessary precaution in heavy cores, the weight of which causes so much "sag" as to produce cracks in the cores. The bolts are inserted after the last of the hay bands, and are surrounded with loam. The form of the casting must be such as to permit of their being drawn out through vent holes cast at the end. Often a deep internal boss has to be struck on a core. Then the end plate is cast with prods, Fig. 71, (7), to assist the adhesion of the loam, the zone of prods being made to correspond with the enlarged portion.

Core Box.—Metal castings are made by forming an impression or mould in sand into which the melted metal is poured. The mould is made from a pattern which sometimes can be made precisely like the casting, but more often must be modified to enable it to be withdrawn from the mould. This modification usually means coring out interior portions. The pattern is made to form exterior outlines, and sand cores of the shape required for the interiors are prepared separately, and placed in position in the mould after the pattern has been withdrawn. For many of these cores, boxes are necessary, in which the sand is rammed, for others plastic loam is used swept on a bar, or on brick-work.

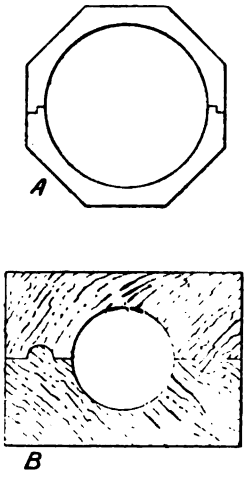


Fig. 72.—Round Core Boxes.

Core boxes vary in design according to the shape of the core required. For convenience in putting in and ramming the sand, they are always left open on one or more sides, and the surface of the core is scraped level across those parts. The inside faces of a box are finished with the same care as a pattern, but the outsides being of no importance, are left rough except on faces where the core cuts through, and which consequently assist in its formation.

The simplest form of core box is a plain cylindrical one. Cores of this shape, in diameters from about $\frac{1}{2}$ in. to 3 in., are so constantly used that standard iron boxes, Fig. 72, A, or of wood, B, are generally kept for making them in, though for other cores, wood or metal boxes are usually made for each pattern as required.

Unlike patterns, core boxes are nearly always taken apart to effect their removal from the sand core. Cylindrical boxes are made in

halves, and fit together with dowels or pins, or in the standard form of metal box a shouldered joint running the entire length is adopted, Fig. 72, A. The halves are clamped together, and the sand rammed in from the ends. In some cases, to economise time and material in the pattern

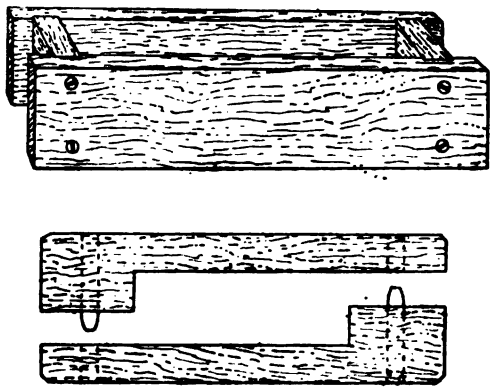


Fig. 73.—Square Boxes.

shop, only one-half of a box is made, where both halves are alike, and two half cores are made and stuck together. In a cylindrical box made in this way the ends are closed and the open part is the joint.

Square cores of the same proportion as cylindrical ones are seldom wanted, but rectangular shapes in which the length does not greatly exceed width or depth are very common. The boxes are made of material ranging in thickness from about $\frac{3}{4}$ in., to $1\frac{1}{2}$ in. according to the length, and the ends are rebated into the sides. Figs. 73-75 show alternative forms. As an alternative to rebating, in large boxes, battens are sometimes screwed on the sides for the ends to bear against, Fig. 75, B, the idea in either case being to prevent the ends from being forced outwards in ramming. Rectangular boxes are generally removed from their cores by simply drawing the dowelled portions apart; or taking out the screws, or removing the clamps, and drawing opposite sides and ends away from the core diagonally. When a number of cores are being made, screws are not put in every time of ramming, but the box is held by clamps, two forms, iron and wood respectively, being shown in Fig. 76, which fit over the ends, and can be instantly knocked off or put on. Very long boxes must be prevented from bulging by battens, or bolts, Fig. 75, A and B.

In many cases where the core is not rectangular in shape, or is rectangular with projections, and depressions in its surface, the rectangular form of box is the basis from which the pattern-maker starts in constructing it. He makes a plain box sufficiently large, and fills in pieces where required. In such cases a loose bottom board with some parts on it is generally necessary, while other parts may be attached to the sides, or bridged across the top.

In complicated forms, cores are sometimes made in parts, and fitted together in the mould. In other cases cores are employed within cores. That is, instead of making the main box exactly like the core, portions of it are treated as a pattern and fitted with prints to receive other cores. This is often done when holes have to be cored through thick portions of the casting, as for instance a cylindrical core through a bossed part. In such a case the cylindrical core fits at one end in a print impression left by the pattern, and at the other into the main core in an impression left by a print in the core box.

In small boxes with one joint through the middle, the joint is arranged so that when the two halves are drawn away from each other

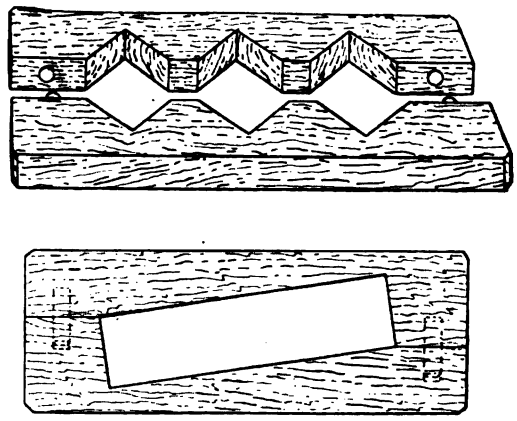


Fig. 74.—Square Boxes.

there shall be no friction against the sides of the core. A box for a cylindrical core of course is jointed through the centre, leaving a semicircle in each half, and the core leaves this without difficulty; but in square boxes the

joint is always made across corners if possible, as in Fig. 74, because ends that are parallel, or nearly so, unless very short, would tear the sand.

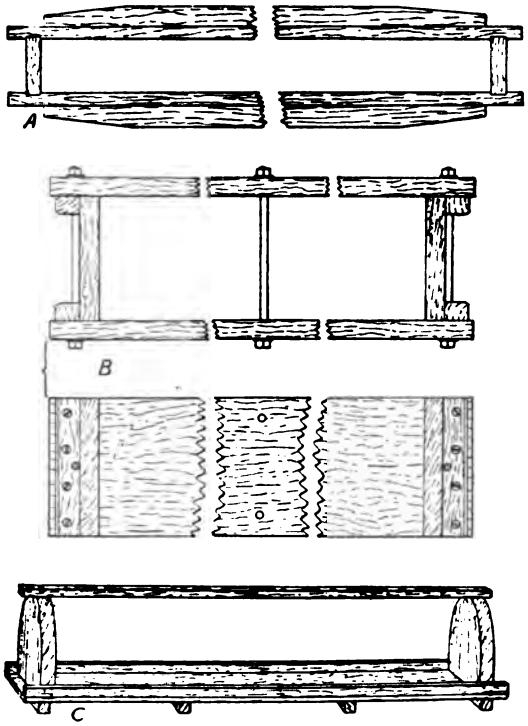


Fig. 75.—Core Boxes.

On the other hand, the boxes for small thin cores are sometimes not jointed at all. This applies chiefly to those in which the thickness of the core is not more than about ½ in., and the length and width not less than 2 in. or 3 in. each way. The shape of the core is then sometimes cut through a solid piece of wood of the correct thickness.

In some cases the open faces of a box greatly exceed in area the closed faces, so that the box looks like a mere skeleton of the core shape, Fig. 75, c. Generally this involves rather more trouble in making the core, but is decidedly more economical in the pattern shop. The amount of economy that can be effected in this way depends entirely on the shape of the core, and in some cases there is little advantage either way between two or more methods of making the box. Economy is greatest when cores with large surfaces, curved in one direction, and straight transversely are required, and the choice lies between building up a box with corresponding surfaces, or making the box with the surface open, and with curved edges at each end to guide the straightedge in levelling the surface off.

When a number of small cores are wanted, it is a common practice to make a box in which several can be rammed simultaneously, Fig. 74, upper figure. For large or complicated cores separate boxes would be best, but a box jointed down its middle is as well adapted for having several core spaces side by side, as only one; and if the cores are plain in character and a quantity are wanted, the slight amount of extra work in cutting the box out for them is well repaid by the saving of coremaker's time.

Core-making Machines.—The practice of making cores in machines has long been in use for plain round cores, which are required in large quantities, but it is only comparatively recently that machines of a more pretentious character have been employed to any considerable extent. A few examples are here illustrated.

Figs. 77-79 show three core-making machines by the London Emery Works Co. They will be recognised as being simply built on moulding machine models, and they illustrate the important extension of machine aids to the making of cores as well as moulds.

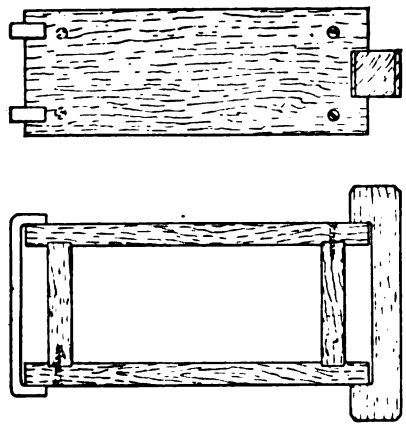


Fig. 76.—Clamps for Boxes.

Fig. 77 is a simple type of hand machine operated by a lever. The halves of a core

box are shown in place, and the ramming is done by hand, and the box halves being thrust together by the upward movement of the table, squeeze the sand into shape. An intermediate frame, removed before pressing, gauges the quantity

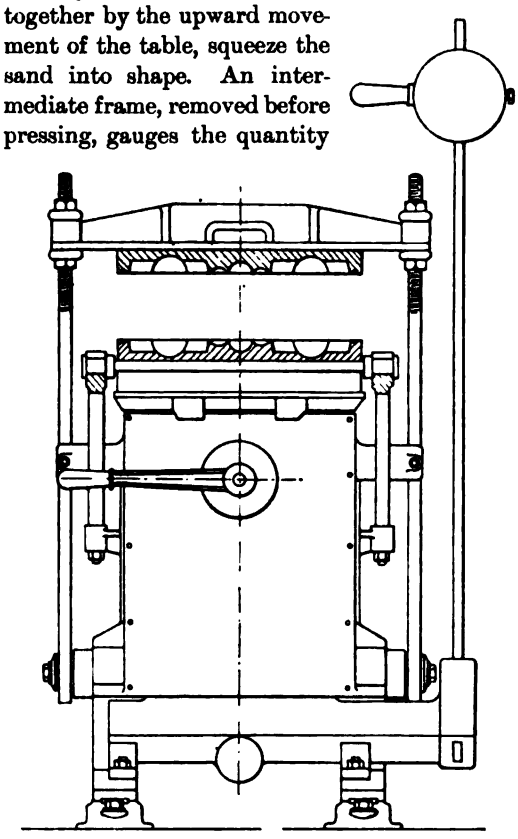


Fig. 77.—Core-Making Machine.

of sand required. The platen can be swung over to clear the table, and is prevented from going back too far by two small brackets, while two springs assist in bringing the same forward.

The next, Fig. 78, is an hydraulic machine with turn-over table, and a platen that can also be swung over clear of the table. The lever situated at the side of the machine works the valve which regulates the inlet and exhaust. It is also shown by the photo, Fig. 79, Plate V.

Fig. 80 is a more elaborate machine, having a trolley track for running cores away as fast as made. The table swings, but the platen instead of being pivoted, is carried by the two uprights at the ends of the machine, and is ran along the horizontal track by the small double-flanged wheels seen in both views.

The machine illustrated by Fig. 81, Plate V., is for making round cores. The sand is rammed by hand, and the core is then pushed out by pulling over the hand lever, or in a larger machine by turning a hand-wheel. The core is left standing on the plunger by which it is ejected. There are three sizes of lever machines, making cores from $\frac{3}{8}$ in. to 5 in. diameter, and up to 12 in. long. The hand-wheel machine makes the foregoing and up to 8 in. diameter × 16 in. long.

Machines are made with a spiral running inside a tube, by means of which the sand mixture is propelled along into a cylindrical tube, emerging as a smooth core.

A core-making machine by Jones & Attwood is shown by Fig. 82; its mechanism is as follows:—

The core is swept up against a steel striking bar, of channel section, but the feature of the machine is the consolidation of the core sand against the core barrel, by the rapid reciprocation of the striking bar A. This is accomplished simultaneously with the revolution of the core against the curved face of the striking bar. The sand supply is carried on the board B, which does not partake of the reciprocating movement. The rate of revolution is 4 to 5 per

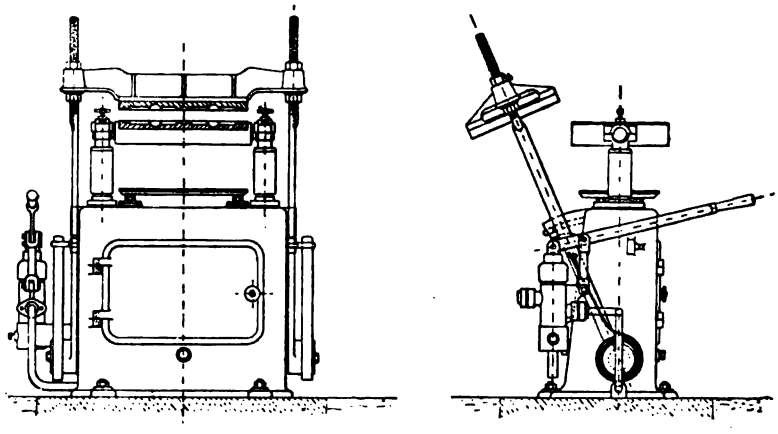


Fig. 78.—Hydraulic Core-Making Machine.



Fig. 69 —Coppersmiths' Shop. (Isaac Storey & Sons, Ltd.)

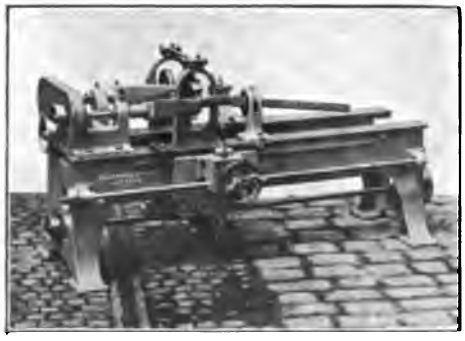


Fig. 70.—Copying Lathe.
(Greenwood & Batley, Ltd.)



Fig. 79.– Core-Making Machine.



Fig. 81.—Core-Making Machine.
(London Emery Works Co.)

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minute, and that of reciprocation from 300 to 340 times a minute. Core bars having necks

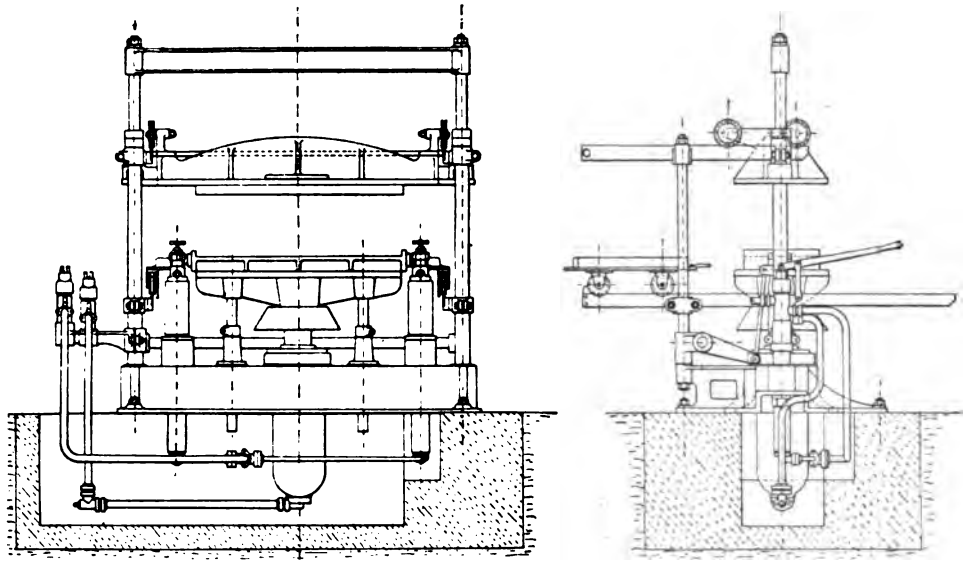


Fig. 80.—Hydraulic Core-Making Machine.

of different diameters are adjusted to accommodate themselves to the fixed driving centre by a vertical movement of the rollers in the carriages C by worm gear, actuated by the

The driving is effected from the pulleys G, fast and loose, operated by striking gear H. A flywheel J on the driving shaft steadies the movement. A worm and worm wheel K drive a sliding collar L, which is connected to, and rotates the core barrel. The reciprocating

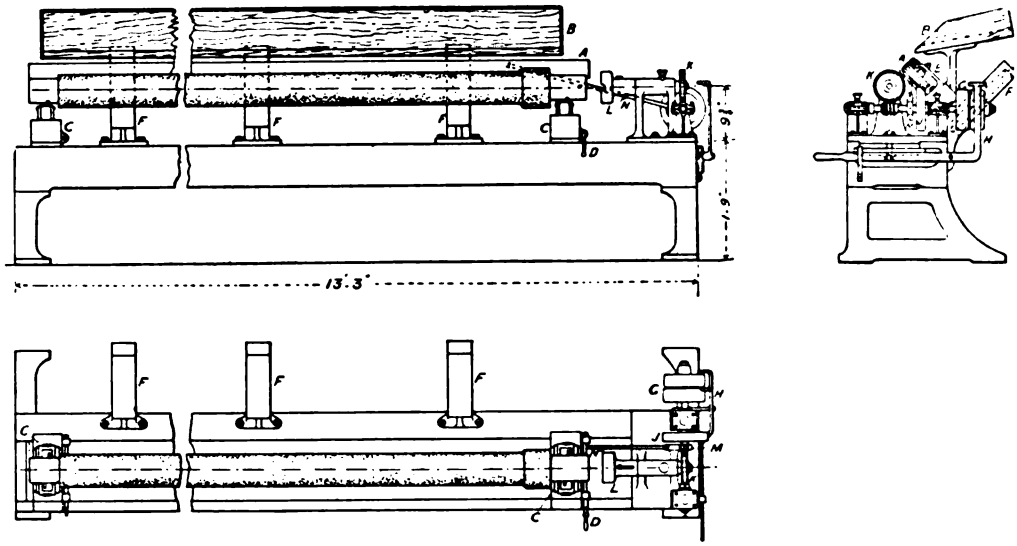


Fig. 82.—Core Machine using a Striking Bar.

handle D. The striking bar A is adjusted for radius by the brackets E, adjustable by their bases in the saddle F by the screws seen.

movement of the bar is derived from the same shaft by the eccentric M and rod N.

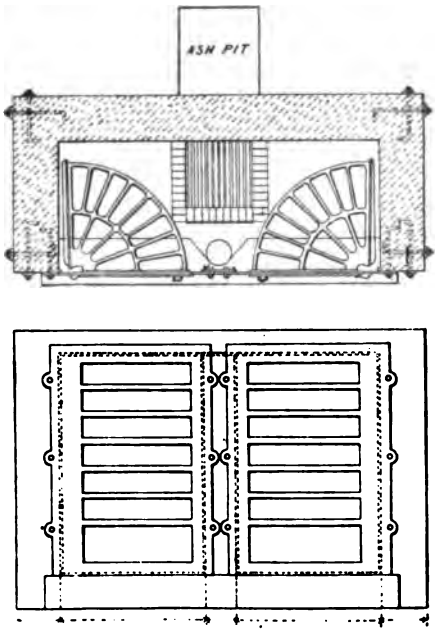
The machine strikes a green sand core in

from one to three minutes, according to the thickness of sand required on the barrel. A stout bar is used, and a thin coating. The capacity ranges from 2 in. to 12 in. diameter by as much as 14 ft. long. The saving over loam cores in pipe work is enormous.

Core Plates.—*See* **Core Bars.**

Core Print.—*See* **Print.**

Cores, Coring.—The term denotes generally an interior portion of a mould, and the method of its formation. Generally, the making of a core in a box apart from the pattern is understood, but that is not an essential condition, since many interior portions deliver freely from the sand. Neither is a false core or drawback understood unless so stated.



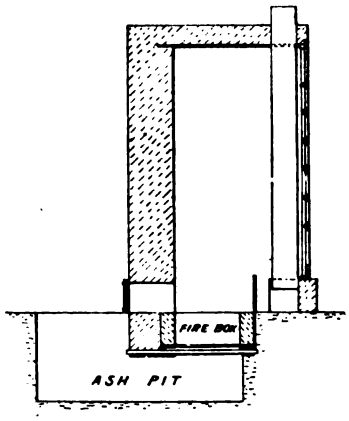


Fig. 83.—Millett Core Stove.

Cores are used for several reasons besides that of the absolute necessity which often exists for taking out hollow spaces with a body of sand distinct from that of the mould. They may be employed, not because they are necessary, but in order to permit of a strong pattern being made, by using prints instead of cutting out the wood and thereby weakening it. The practice of coring alternatively to self-delivery is often available, and either would be adopted by different men when jobs lay on the border line. The general practice of different shops also varies much, some habitually preferring cores to the other method.

Cores are made in green sand, dried sand, and loam. Green sand is restricted almost wholly to large masses that deliver from the pattern, or which are of plain outlines. These are sometimes rammed within pattern spaces, but often also in core boxes. They may or may not be skin dried. No cores with flimsy sections can be made thus. But such cores are suitable for some classes of work, essential in others, as in rain-water pipe, and similar light castings where the presence of hard cores would cause risk of fracture of the shrinking metal.

Dried sand cores form the vast majority used, and these are mostly rammed in boxes, though occasionally in patterns. *Core Sand*, as it is termed, is hard when dried; and when supported with grids, rods, or nails rammed in while green, will withstand any liquid pressure possible in a foundry mould without yielding. There is hardly anything so intricate that it cannot be cored in dried sand.

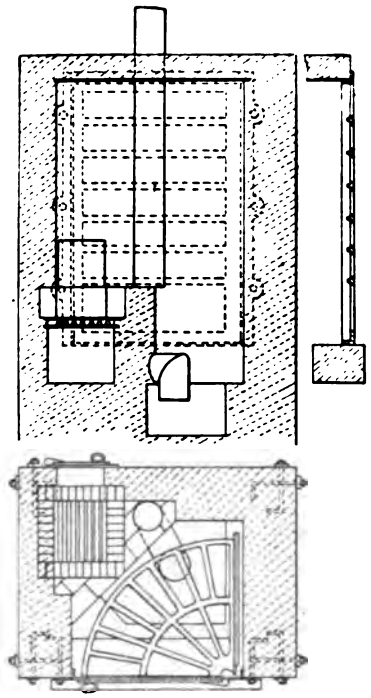
Loam cores are swept on revolving bars, or with strickles against guide irons, or around bricking. They differ from core sand work in the material being made plastic with water. They are therefore invariably dried.

Core Stoves.—A special group of drying stoves. In strictness the latter term denotes the larger stoves used for large moulds made in loam; and in strong sand for dried sand moulds. But large cores are also as often put into them. The distinction is hardly one of size therefore, and all stoves are thus indifferently known by both terms.

Small core stoves proper are either built of

brick like the large ones, or they are wholly of sheet-iron or steel. The advantage of using brick-work lies in its being a bad conductor of heat, that of iron or steel lies in its portability, and sometimes its greater convenience. In small brick-built core stoves the fire is not generally in the floor, but in a grate raised up over an ashpit underneath, and the heat passes underneath tiers of shelves, thence out through a tall chimney of brick or sheet-iron. The stove is closed with sheet-iron doors, which on being opened afford access to all the shelves at once. Such stoves may measure from 4 ft. 6 in. length by 3 ft. to 4 ft. in height; and 2 ft. 6 in. to 3 ft. deep.

The best small oven is that which combines hinged shelves with a bricked body, the Millett, illustrated in Figs. 83, 84. It retains the heat, and each hinged shelf is provided with its own door, which is far better than the single door exposing all the shelves to cold air. The hinging is also better for the core boys, who have not to reach over into the hot spaces. Moreover, opening the swinging shelves closes the space behind, because each shelf has a rear door in addition to the one in the front, and the rear door fills the opening when the shelf is outside the oven. The Millett is also made portable, being built of iron for use where it may not be convenient to erect a brick oven.



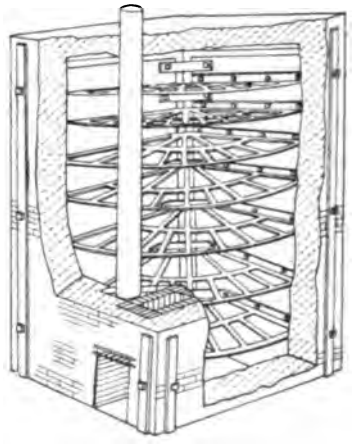


Fig. 84.—Millett Core Stove.

Core Trestles.—Trestles of cast iron on which core bars are rotated for the sweeping up of circular cores in sand and loam. They stand on a broad foot or feet, and have vee'd recesses in the top to serve as bearings for the bars of different diameters. The large trestles rest on the floor, the small ones are stuck into a board resting on the larger trestles.

Corliss Engine.—This is an American invention which long enjoyed a reputation for economy based on a misconception of the real cause of this. The Corliss valve is simply a cylindrical valve with an angular rotation in a cylindrical seat not unlike an adaptation of the ordinary common plug tap. The valve is rotated by a rod and arm pulled by an eccentric, but in the course of the arm is a trigger or detent which is tripped by the action of a cam controlled by the governor. Since the valve is opened against the pull of a spring, the release of the trigger allows the spring to close the valve rapidly, and shut off steam quickly. Much was credited to this rapid cut-off, and to the automatic variation of the point of cut-off, simply because the Corliss valve did give good results. There are four valves to each cylinder, placed in the four "corners" of the cylinder, looked at in side elevation, the steam valves being at the top. Thus when the valves open for steam admission, all water entering with the steam is shot across the cylinder into the

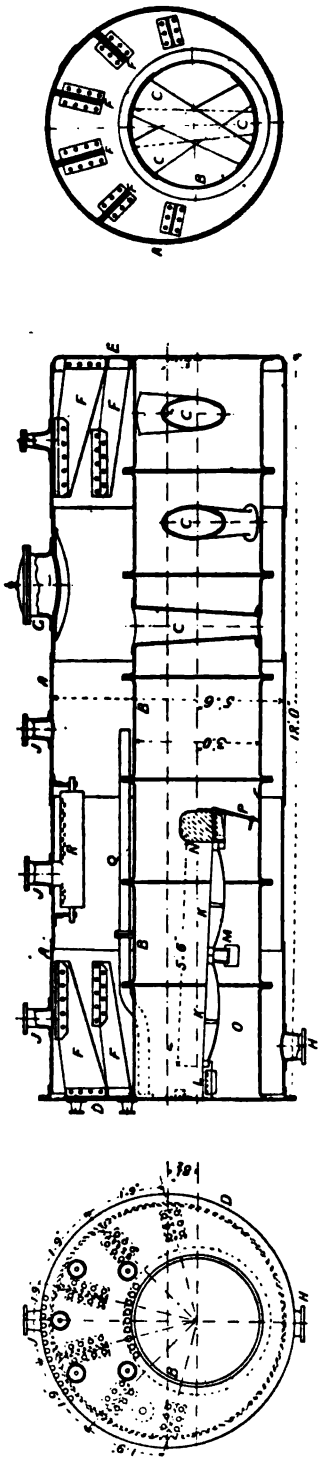


Fig. 86.—Cornish Boiler. (Galloways, Ltd.)

exhaust ports opposite, and these being right on the bottom of the cylinder give good drainage, and this undoubtedly contributes to economical working.

In most Corliss gears each valve is connected by a short rod (which contains the trip motion in case of the steam valves) to a rocking disc (*see* Fig. 85, Plate VI.). This disc carries the four pins to which the short valve rods are attached. Behind the disc is the pin on which the eccentric rod is coupled, which gives the angular rocking movement to the disc.

The trip cam or trigger is connected to the governor, and its position is varied by this so as to trip the valve gear, and automatically vary the cut-off of the steam as the load varies. The Corliss gear can only be employed for comparatively early cut-off, for the trip action cannot take place except on one direction of movement of the gear. It cannot occur after the eccentric has reached its full throw.

Many modifications of the gear have been introduced, but none ever improved materially upon the Inglis gear as first introduced by the late William Inglis. With the use of superheated steam the Corliss valve is rapidly going out of favour, for it is not a suitable valve for temperatures above 500° F. Its early employment coincided with the first general use of the horizontal engine and a general forward movement in speeds and pressures, and the introduction of steel, and all these things rendered economies, and better working possible; for which the Corliss engines took much undeserved credit.

The early Corliss engines were made on different lines from previous engines, the cylinder standing on feet on the foundation, and being connected by a long trunk frame with the crankshaft pedestal, which also stood on a foot piece. Clearance spaces were reduced to a minimum, and the Corliss engine was a big advance on the common type of engine, but in no way superior to then existing automatic cut-off variable expansion engines of piston valve type and drop valve type of English origin, which had been developed long before the Corliss valve.

Cornish Boiler.—A cylindrical boiler with its axis lying horizontally, and its furnace occupying an eccentric position in the vertical plane, its centre lying below the centre of the shell. In Continental practice the furnace is also set laterally to one side of the shell centre with the object of leaving more space for cleaning at the bottom of the shell.

The term *Cornish* arose from the fact that the type was first introduced into Cornwall by Trevithick. From it has branched off the Lancashire boiler, the Galloway boiler, and various modifications, as the Breeches flued, and multitubular.

As a small unit, the Cornish still retains a useful place, because it is fairly efficient, and being of simple construction

is easily attended to. Its dimensions range from about 3 ft. to 6 ft. in diameter, by from 8 ft. to 24 ft. in length. But when the large sizes are required it is preferable to have a Lancashire, or two flued boiler. Cornish boilers must be built over brick-work flues to permit of the proper utilisation of the furnace gases.

F are plate-gusset stays which stiffen the otherwise weak areas of the front and back plates. They are united to the plates and shell with angles. G is the manhole, H the stand pipe or seating for the blow-off bend, J is the similar stand pipe for the stop valve whence the steam supply is drawn. J J are for safety valves. K K are the fire-bars resting on the dead plate

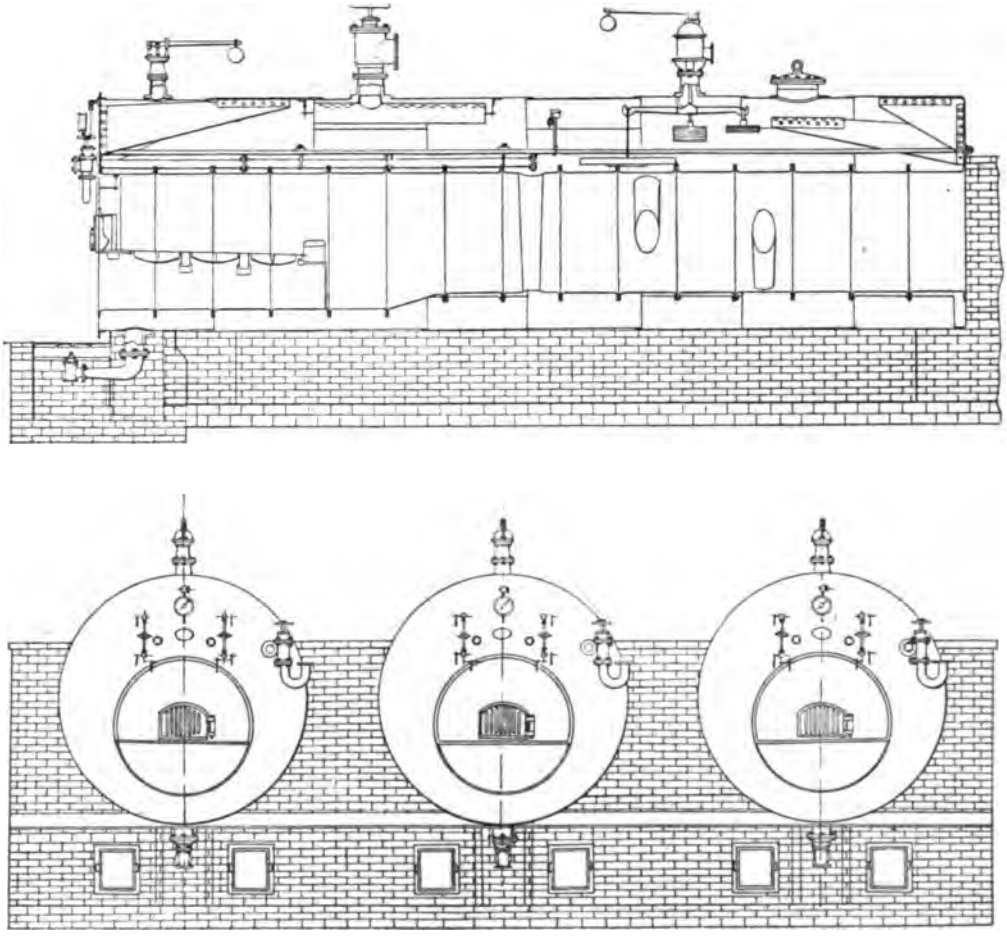


Fig. 87.—Battery of Cornish Boilers. (Daniel Adamson & Co., Ltd.)

Fig. 86 illustrates a Cornish boiler, the following being its principal details:—A is the shell, B the furnace flue, of the Adamson flanged seam type; fitted with three conical tubes C. The front plate D is fitted with an angle ring to the shell, and the furnace flue is flanged to meet it. The back plate E is fitted to the shell by flanging, and the furnace flue fitted similarly. L, on the bearers M, and on a ledge of the bridge N; O is the ash-pit, and P the damper door for it.

Fig. 86 only shows the boiler, apart from its mountings, seatings, brick-work flues, &c. These are shown for a battery of boilers in Fig. 87. These boilers represent the best modern practice in the following respects:—The shell is

built up of single rings, riveted longitudinally with double-butt straps, and circularly with single-lap riveting. The butt straps are kept to one side of the centre in order not to interfere with the holes cut for the various mouthpieces, or standards. The manhole has a large strengthening ring twice the diameter of the hole. No cast iron is used in stand pipes, but flanged steel only.

With regard to the occupation of so large a cross section of the shell by the furnace flue, the difficulty that results is the smallness of the space left between the bottom of the flue and of the shell. In one design, the hinder portion of the flue from a little way beyond the bridge is reduced in diameter, so giving more space beneath for examination, and circulation. The

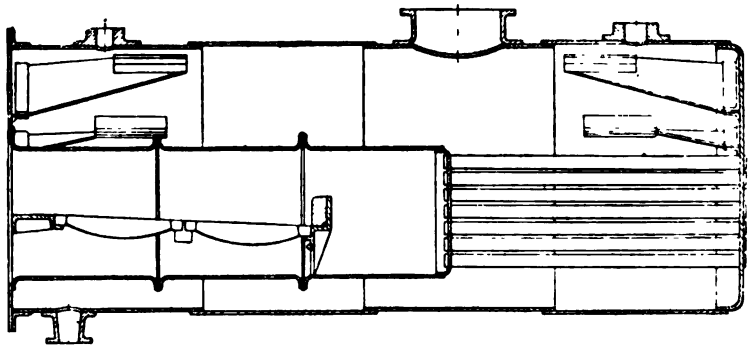


Fig. 88.—Multitubular Cornish Boiler.

reason why the latter is so bad is that while steam is being got up, the top of the shell becomes much hotter than the bottom, and hence ensues expansion and straining of the plate. Circulation is improved by the fitting of the cone tubes shown. The water at the bottom is sluggish, and if deposit is allowed to accumulate matters are made worse. Formerly the feed was brought in at the bottom, but never in present practice, because the cold feed aggravated the bad circulation. It is now brought in, Q, just above the level of the furnace crown, and distributed well within the boiler.

Some Cornish boilers are made with multitubular arrangements, that is, the furnace flue is cut short by several feet, and given up to smoke tubes, Fig. 88. These increase efficiency, but are only desirable with clean water, not liable to cause deposit and incrustation, since cleaning round the nests of tubes becomes difficult, or impossible.

For the methods of manufacture of Cornish boilers, *see* **Lancashire Boiler.**

Cornish Engine.—The Cornish engine properly so-called is a steam engine in which the method of working the steam is peculiar.

In a beam engine, steam was admitted above the piston as this descended in the cylinder. When the piston rose again, a communication was then opened between the top and bottom ends of the cylinder, and the cylinderful of steam was transferred from end to end of the cylinder. Then when next the piston descended, the steam now below the cylinder was discharged through another valve to the condenser. The top end of the cylinder was never in communication with the cold condenser, and therefore never was in contact with steam much less than 212° Fahr. in temperature; nor with the low pressures of the day was it ever much hotter than 212° Fahr. The temperature range in the cylinder was small, and the steam condensed in the cylinder was also small, and to this is to be attributed much of the economy of the Cornish pumping engines. The piston was drawn upwards in the cylinder by the weight of the pump spear rods, which in their descent also did the work of pumping the mine water to the surface. The "vacuum" below the piston drew it down, or rather allowed the steam, at atmospheric pressure above the piston, to weigh it down, and lifted the spear rods. Movement was very slow, and the swinging beam was stopped by coming into contact with stops or spring beams, which continued to exist by name long after their use was rendered unnecessary in the rotative engine, in the shape of the rigid cast-iron floor beams to which were attached the brackets of the radius bars of the Watt parallel motion.

Great rivalry existed in Cornwall in respect of the duty of the pumping engines of the different mines. This duty was stated in periodical reports in terms of the millions of foot pounds of water pumped per bushel of coal of 94 pounds. In order to increase this duty the cylinders were well lagged with, first, an air space, then brick-work, next plaster, and finally a sheathing of timber. Some engines were provided with flues round the cylinder through which the furnace gases were allowed to pass. Jacketing with steam was usual, but the Watt method of passing the working steam through the jacket was not followed, there being a separate system of steam supply. By careful attention to principles and details the average duty of Cornish pumping engines was increased from 28 million pounds in 1823 to 45 million in 1832, 54 million in 1840, and 60 million in 1843, while the maximum recorded duty rose from 51 million in 1823 to no less than 107,500,000 in 1842. These old pumping engines had steam cylinders of 80, 85, and even 90 in. diameter; and in 1824 a double cylinder Woolf, or compound engine is recorded of which the great cylinder was 70 in. An engine at the Consolidated Mines had an 80-in. cylinder, with a stroke of 11 ft.

Corollary.—In Euclid a corollary is an inference or consequence which at once follows from the demonstration of a proposition. The famous *pons asinorum* (the fifth proposition of the First Book of Euclid), which runs, "The angles at the base of an isosceles triangle are equal to one another; and if the equal sides be produced the angles on the other side of the base shall be equal to one another," has the corollary, "Hence every equilateral triangle is also equiangular."

Corrective Gauge.—*See* **Plug and Ring Gauges.**

Corrosion.—*See* **Barffing, Boiler Explosions, Feed Waters, Iron, Protective Coatings, Rust, Steel.**

Corrugated Sheets.—*See* **Sheets.**

Corundum.—An abrasive which has some points of superiority over emery, the latter being an impure form of corundum. It is found in the form of crystals embedded in feldspar and other materials. Corundum costs rather more than emery, because of the expense of separation, emery being found in rock form. Corundum has advantages particularly for grinding steel tools, because it does not glaze nearly so much as emery, having less impurities of a non-cutting order, and therefore the useless friction of emery, which generates excess of heat, is avoided. A greater hardness can be given to corundum wheels than to those of emery.

Until recent years corundum was unobtainable in any quantity, so that its use was very restricted, but the opening up of large deposits chiefly in Canada gave an impetus to the employment, and it now rivals emery closely. The shapes of corundum wheels will be given under **Grinding Wheels**; it is also made up into sticks, &c., similarly to emery.

Cottar, or Cotter.—This is a form of wedge employed for holding portions in place, or uniting ends of various kinds. It differs from the key in being narrow by comparison with its depth, the amount of the latter being necessary to prevent shearing off under strain. The cotter may be applied as in the **Cotter Bolt**, p. 14, Vol. III., or to draw parts over one another, as in the **Connecting Rod**, advantage being taken in the latter to absorb wear from time to time by means of the cotter, drawing the bearing brasses together. A gib is usually employed in conjunction with the cotter, to prevent the latter spreading the outer portions of the bridle, such as in a connecting rod.

Cotters for bolts, and for uniting pump rods have only a very slight taper, so that slacking back is guarded against; a split pin is sometimes passed through the tail for assurance. But in the cotters with a good amount of taper, necessary for taking up wear by a small movement, adequate means of locking must be provided, either by set-screws pressing on the sides, or having a screwed tail on the cotter, held by lock-nuts, so that it cannot shift endwise.

Cotters are either black or bright, the former being left as forged, and fitted by filing, the latter machined or ground bright all over, the choice depending on the class of work in hand. Heads are often forged with cotters, to give a larger bearing surface for hammering on, the practice being often adopted where frequent removal and insertion is necessary.

Cotton Ropes.—Used largely for driving purposes, their rivals being ropes of manilla, and Russian hemp. Manilla ropes are used to a large extent in America, but cotton ropes are employed here to the almost total exclusion of hemp. The rope-driven overhead travelling cranes must be credited in a large degree with having demonstrated the superiority of cotton to hemp, for the conditions are very trying, due to the small pulleys and high speeds, which soon find out the weak places, and cause fraying, or stretching, or frequent fracture at the splice. Frequent stoppage for resplicing, or a spare rope are the only alternatives.

Experience has demonstrated that the strong tough hemp is not so flexible as the cotton, and that it stretches more. The three essentials in a successful rope are strength, flexibility, and resistance to stretch, in order to obtain a long life; these are found present in a greater degree in ropes of cotton than in those of hemp.

The severest test that can be imposed on a rope is the alternate bending and straightening as it passes over the pulleys, in this respect resembling the band saw. The fibres of a hemp rope in sliding over one another during this bending and straightening rub themselves to powder, but cotton only slightly by comparison. The number of strands has, however, an influence here. The fewer they are, the more flexible the rope. Mr Hart's long experience is in favour of four strands, as being more durable than seven, or than three. Seven strands do not make a rope flexible enough for the requirements of power transmission, though wire ropes for hoisting, &c., are often composed of seven strands. Four-strand is sufficiently flexible for all purposes of power transmission, and being more nearly round, presents more driving surface to the pulley than a three-strand rope does.

With regard to the resistance to stretch of cotton ropes, Mr Hart cites the cases of some of his ropes that have been running for periods of from five to twenty years without requiring any tightening—a remarkable record. Tests of resistance to stretch made by David Kirkaldy & Son showed little stretch. A rope of 4·78 circumference, with a load of 1,775 lb. (above the average working stress) stretched only 2·80 per cent.

The resistance to friction in the Lambeth rope is provided for by the outside twisted cords, ten of which are wound spirally round each strand. This protects the strand, the working part, from contact and wear in the grooves.

The weight of a rope is of importance. If weighting material is added to pure yarn, as in ropes sold by weight, that means more load put on the machinery. The annexed table shows the weights of the Lambeth ropes.

Diameter in in.	1	1⅛	1¼	1⅜	1½	1⅝	1¾	1⅞	2
Diameter in mm.	25	28½	32½	35	37½	40	44	47	50
Weight per yd. in lb.	oz. 15	lb. oz. 1 3½	lb. oz. 1 7½	lb. oz. 1 12	lb. oz. 2 0	lb. oz. 2 4	lb. oz. 2 9	lb. oz. 2 14	lb. oz. 3 6
Weight per metre in grammes	460	605	730	870	990	1,120	1,270	1,430	1,670

Cotton ropes require from 10 ft. to 12 ft. length of splice. When spliced, they are put on the small pulley first, and as far round the large pulley as it will go. It is lashed there, but so that the rope is free to slip through it. On barring the pulley round, the rope will slip into place.

The subject of pulleys for cotton ropes, systems of driving, &c., will be found under **Rope Driving.**

Cotton Rope Travellers.—As distinguished from the now obsolete "cotton *cord*" traveller. The cotton cord traveller was driven by a high-speed rope of small size, generally $\frac{5}{8}$ in. diameter, and running at 5,000 feet per minute. This cord extended the length of the runway, and

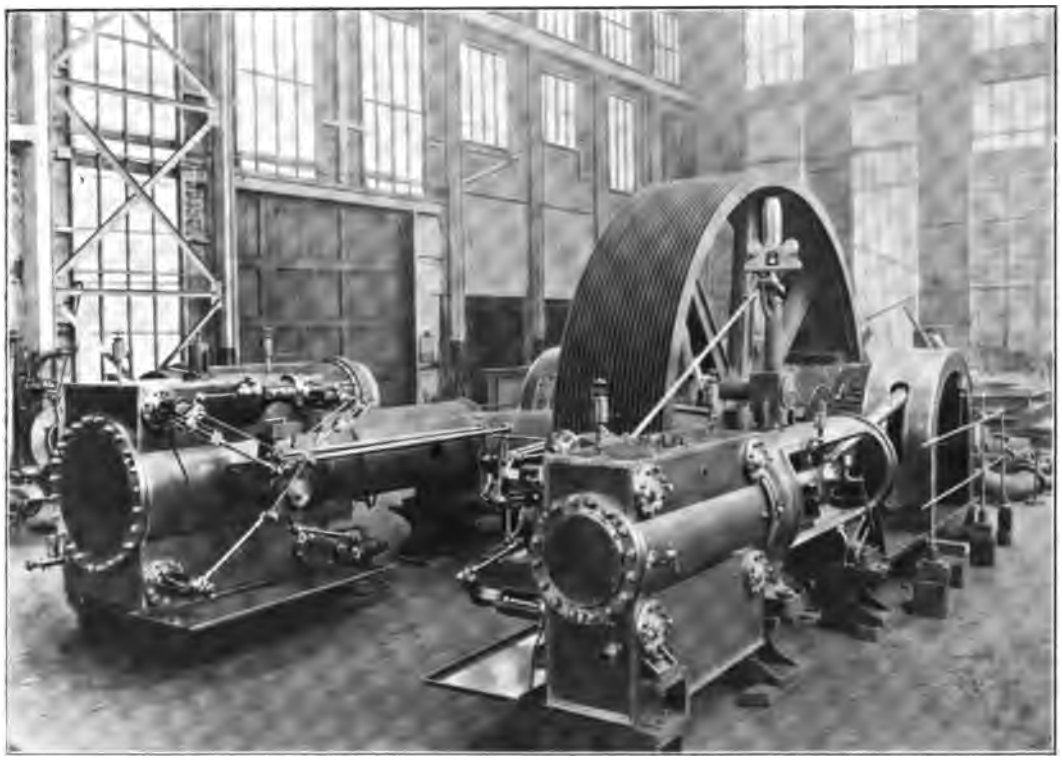


Fig. 85.—460-HP. Compound Corliss Engine. (Cole, Marchent, & Morley, Ltd.)
H.P. Cylinder, 16½ in.; L.P., 33 in.; Stroke, 42 in.; 85 revs. per minute.

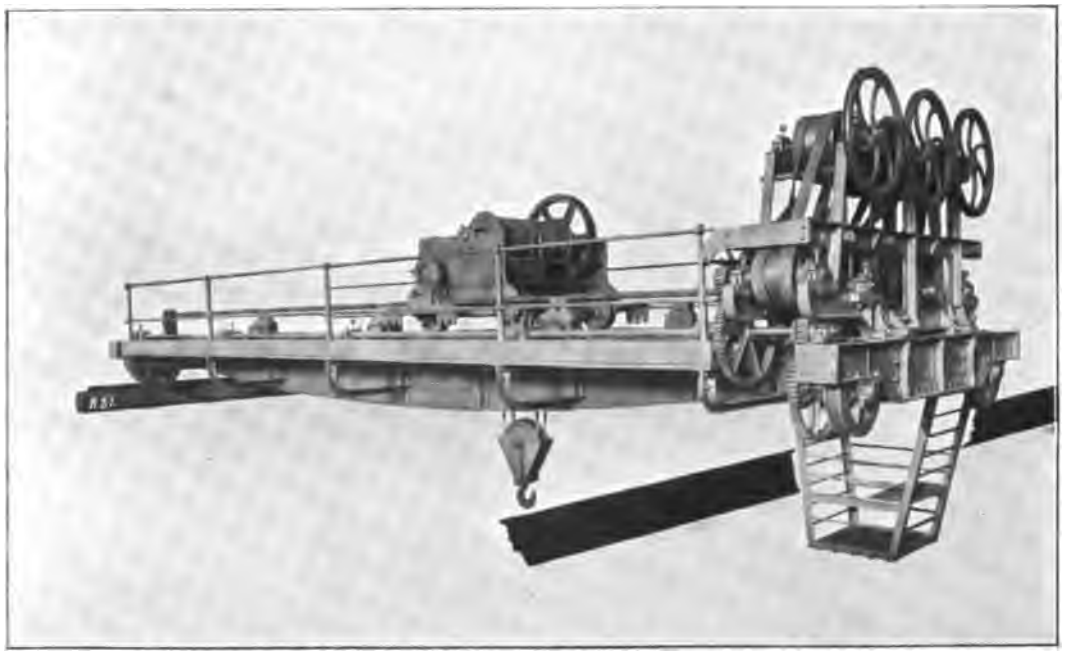


Fig. 89.—20-Ton Cotton Rope Traveller. (Thomas Smith & Sons.)

To face page 84.

was deflected and passed over the crane itself, driving each of the three motions direct by means of reversible friction cones. The cotton *rope* traveller receives power from a rope drive running the length of the crane track, and transmits it to the various motions by means of open and crossed belts arranged at the end of the traveller. All motions are controlled by levers within reach of the driver, who is seated in the cage suspended from the girders. This class of traveller, which has reached a high pitch of perfection, is now, however, rapidly giving place to electrically driven cranes wherever current is available. Fig. 89, Plate VI., shows a 20-ton cotton rope traveller.

Cotton Tapes.—Used for lubricating bearings by capillary action.

Counter.—*See* **Speed Indicators.**

Counterbalancing.—*See* **Balancing, Balance Crane.**

Counterbore.—*See* **Drill.**

Countershaft.—*See* **Shafting.**

Countersink, Countersinking.—Enlarging a drilled or punched hole, to the section of a truncated cone, for the reception of a screw or rivet head to lie flush with the surface. Such a hole is said to be countersunk. *See* **Bit, Rivets** for examples.

Counterweight.—*See* **Balancing, Crank, Crank Turning.**

Couple.—*See* **Statics.**

Coupled Wheels, Coupling Rod.—Locomotive wheels are connected with coupling rods in order to distribute the weight necessary for adhesion between all the wheels so united.

Couplers or **Automatic Couplings.**—The coupling arrangements for the carriages and wagons of railway rolling stock, which couple by the impact of the parts, so avoiding the necessity for men getting between the vehicles to secure them.

The use of these has been compulsory in the United States since 1900. In Britain there is not the imperative necessity for their employment that there was in the States. Thus, in 1898, when 70 per cent. of American cars were fitted with such couplers, 1 in 486 railway servants were killed, while here the proportion was only 1 in 1,060. Hence though legislation has been attempted here, it has not been carried into law, and only a small proportion of the vehicles on British lines are so fitted. Other countries are in the same position as ourselves in this respect.

The original American system of link and pin coupling without side buffers was so bad that the case for an automatic safety device was far stronger than in England. To use devices here with existing stock means a costly coupler and buffer combined, for all our trucks have side buffers; and it must also be capable of adoption with all the couplings already in use in this country during the period of transition from the old to the new system.

The problem is far more difficult than it would appear at first sight. Hundreds of patents have been taken out for automatic couplings, but only a few types are in general use. These are, the Norwegian hook, the standard type employed largely on the Indian State Railways, and in Australia. The Master Car Builders type (M.C.B.), which embodies certain proportions and dimensions, and the Contour Line, but which is varied in regard to hinging the knuckle, and the arrangement of the locking device. The Janney is the best known of these, the Gould, and Perry Brown being others. The difficulties that arise are due to wear, to the effect of sharp curves, want of automatic coupling of the brake pipes, and passenger communication. Automatic couplers have not proved an unqualified success, for many cases have occurred of trains parting, due to failures in the coupling.

Couplings.—Specifically the agencies by which shafts are united, as box, flange, cone vice, clutches of various kinds, described under their special headings.

Cover Strip.—A butt strap. *See* **Riveting.**

Cowburn Valve.—A **Dead-load Safety Valve.**

Cow-Hair.—Used in loam moulds, and as a non-conducting lagging for cylinders, &c.

Cowl.—The top of a ventilating pipe.

Cow-Mouth Chisel.—*See* **Chipping Chisel.**

Cowper Stove.—*See* **Hot Blast Stove.**

Crab.—The simplest kinds of hoisting machines after the pulley blocks are the various

forms of hand crabs, the convenience of which lies chiefly in their portability; but which have besides the merit of cheapness, and very large capacity for lifting. They can be used in combination with sheer legs, or alone. They may lift direct from the barrel for quick haulage and light work, or their power can be applied to operate pulley blocks for heavier loads with slower action. The crabs themselves are made

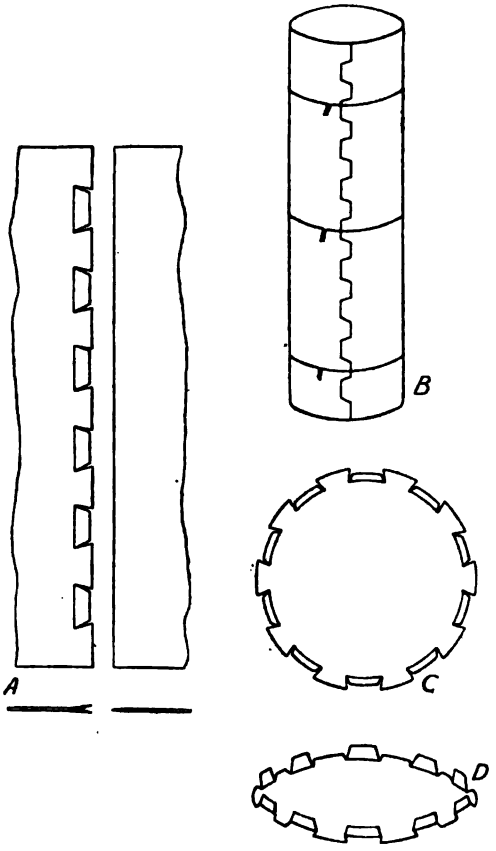


Fig. 90.—Cramped Joints.

with single, double, or treble purchase. Many are of single purchase only, others have single and double in combination, while the heavier class have all three in combination.

From the simple crab to the crabs actuated by power is a long stride. Steam, and electricity are used direct; or indirectly, by conveying the power to the crab by shafts, gears, and ropes. The power crab occurs in a far wider range of design than the hand types. Notes on these will be found under the different forms of overhead travelling cranes described.

Cramped Joint.—A joint used by coppersmiths and tinsmiths. The edges to be united are notched, Fig. 90, A, on one piece, and plain on the other. The notchings or cramps are turned upwards and downwards alternately, and the plain edge—thinned down—is inserted between them. The cramps are then hammered down, the joint wetted with borax in water, and spelter ran along and melted into the joint, which is afterwards smoothed and cleaned. Cylinders, B, are secured with binding wire. C, D show a disc cramped for insertion in the bottom of a vessel. Cramping is adopted in much heavy coppersmiths' work. It is necessary in thin sheet, for which a simple lap joint would not be secure enough. It is done in the coverings of steam domes and similar work, being alike suitable for flat sheet, and cylindrical, and spherical objects.

Crane.—A term of very wide scope. Originally it denoted the raking jib crane, which presumably bore some resemblance to the neck of the bird, its namesake. Probably the earliest cranes were rigid poles operated as levers; followed by the ship's derricks, by the walking cranes on the banks of tidal streams, in which a man walking within a large wheel turned it, winding the rope around the much smaller capstan barrel on the same axis. The derrick was the favourite type before the advent of the hydraulic and steam cranes, and was the subject of numerous patents, some of which improvements are still retained.

All the early cranes were fixed, and operated by human power. Not till about the middle of the eighteenth century were steam and water applied successfully to the operation of cranes. Steel was not then available, and wrought iron scarcely entered into their construction, save for the rods and shafts. In a collection of pictures of old cranes made by the writer, the remarkable feature is the predominance of timber, and of cast iron. Both were used freely for posts and jibs. Portable cranes with timber trucks came later, and as that design rendered a deep post going below the ground impossible, the balance type resulted, still hand operated. The overhead travelling crane is also rather early,

dating from about 1840, and in this timber beams were used. The introduction of water and of steam at nearly about the same period effected vast changes in design. The first named created a new type entirely, but steam did not. It only modified the framings; the trucks and the overhead devices rendering the cranes more complicated, but not changing their general outlines. Other changes were effected in the travellers, due to differences in driving, whether by an engine on the crab, or from one elsewhere, driving the crab and gantry by means of square shafts and gears, or by flying ropes. Details of these and other cranes will be found under their proper headings.

If we attempt a rational division of cranes, there are three very broad main types apparent; classed as fixed, portable, and travelling respectively. Whether any of these are operated by hand or by power is rather a subsidiary issue, because a large number in each group may be actuated alternatively. But there are several which can only be power operated, as, for example, all the big cranes, to whatever group they belong.

The *fixed cranes* include the following, using the term in its most comprehensive sense, and not restricting it to cranes with jibs. Pulley blocks, including blocks worked by hand, by compressed air, and by electricity; crabs, winches, hoists, and winding engines operated by hand, steam, and electricity, a very extensive group destitute of jibs. Cranes having triangular framings, with horizontal jibs, or raking jibs—the cranes proper, also an immense group. It includes the whip cranes, wall cranes, wharf cranes, derricks, sheer legs, coal hoists.

The *portable cranes* include those with trucks on wheels, the portable balance cranes, travelling derricks, excavators, floating cranes, and many of the long-armed cranes and transporters, and the light portable hoists.

The *travelling cranes* form a large group of increasing importance. To this group electricity was first successfully applied. It includes overhead travelling cranes, goliaths, gantry or portal cranes, single rail cranes, travelling air hoists, bridge and long-armed transporter cranes, block setters, or titans.

Most of these cranes receive treatment under their headings, and also the agencies by which they are operated. These are hand, steam, water, compressed air, and electricity. A few types afford examples of operation by each method. But in some, the larger cranes particularly, the choice of agencies generally lies between two only; as steam, or electricity, or steam, water, and electricity. The latter, and compressed air come into close rivalry, as in many of the lighter groups of hoisting machines, notably hoists, carried on overhead trolley trucks.

Crane Beds.—These are the fixed bases, in, and on which the superstructure, the actual hoisting machinery is carried. They are fixed absolutely by firm anchorage to a foundation, on, or in the earth; or they form a portion of a portable truck, in the portable and locomotive cranes. As very often beds of identical form from the same patterns are sometimes attached to trucks, we will consider the subject from the wider point of view.

The crane beds proper include two main types; those which are contained wholly on the surface of the ground, and those which are not. The first are often termed steps, or footsteps, as in the case of the derrick bases. But a footstep and bed are combined in many cases; the bed on the level, the step deep down in the ground. These variations in design correspond respectively with the short post that does not go below the ground level, and the long post that passes several feet below. In each case deep foundations are required; but in one they are built in concrete or masonry, in the other a casting, often the step casting, affords stability against the overturning of the crane.

There are always two functions at least to a crane bed, often three. One is as a receptacle to the post, which fits into a hole bored in the bed, or over a pin standing up from the bed (as in most derrick cranes); the second is as a stable base to prevent the crane from overturning, or to act in conjunction with some other device to prevent it. The third often is to receive a ring of teeth for slewing, or to receive brackets, bearings, and other fittings for the operation of certain parts of the mechanism.

When a bed or step is laid on concrete or masonry, it is held down securely by long bolts that are passed through the mass, and retained at the bottom by their heads against broad washer plates. The crane therefore would be built over with concrete, and bolts coming up through the latter make connection with the top plate. Or the footstep may be a casting distinct from the washer plates, provided each is secured in concrete or masonry.

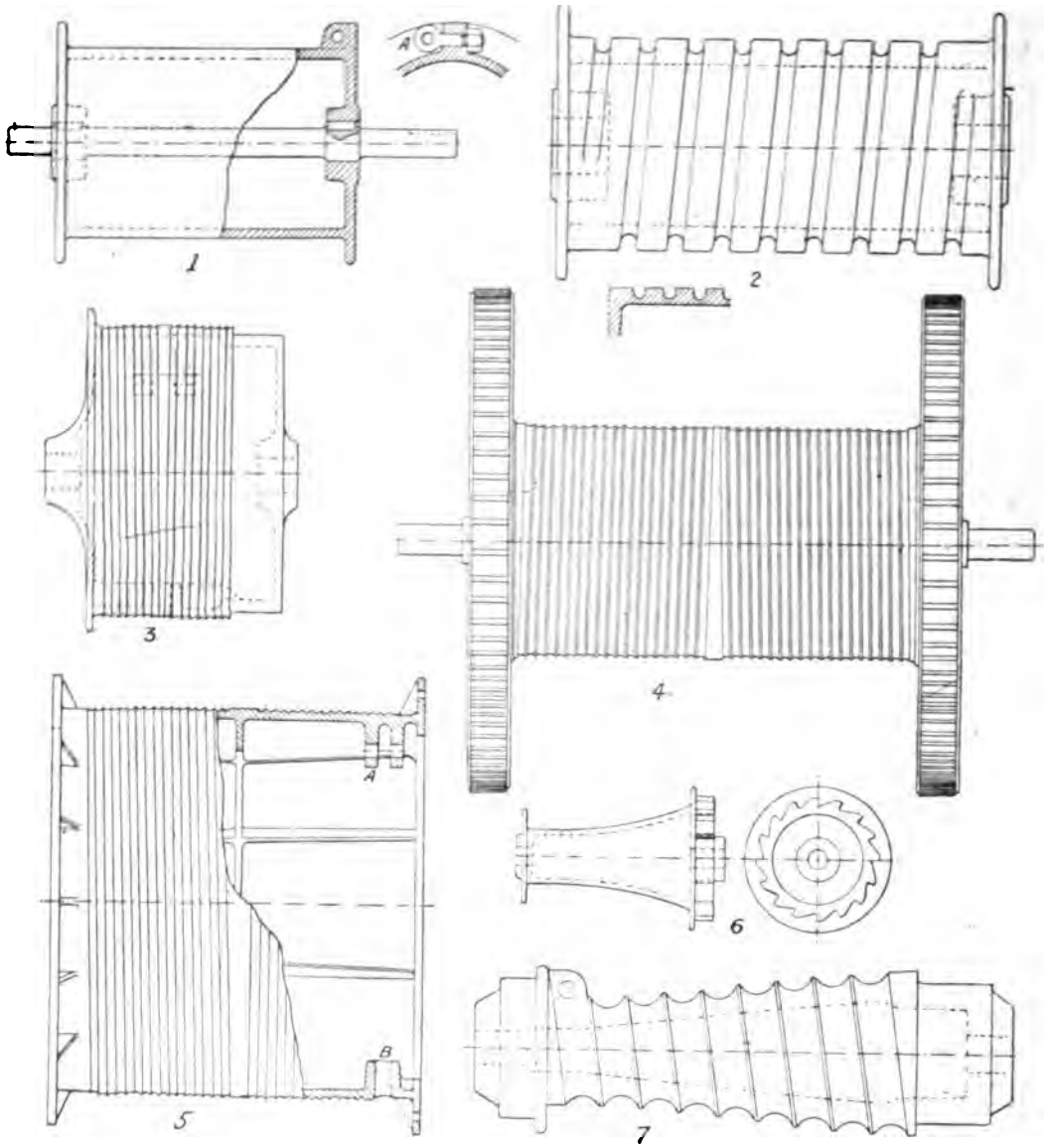


Fig. 91.—Types of Crane Drums.

have to fracture the bolts, or pull up the concrete bodily, before it could overturn.

When a footstep is laid deep down in a foundation for a deep post crane, that also may

If a bed does not become pulled up, which can hardly ever happen, it may become fractured by bending stresses imposed by the lifting of the load at long radii, and by the shocks

which often occur in hoisting and lowering. Hence beds should be deeply ribbed, and when the design is such as to permit of it, considerably deeper next the central boss than at the bosses for the hold-down bolts.

The beds or trucks of portable cranes may be wholly cast, or a cast centre may be inserted in a plated framing. The last is the method almost universally adopted for heavy cranes, the former for the lighter ones. A boxed section of framing is preferable to a ribbed one, but the bottom need not be closed in. Or it may be simply ribbed without and within to impart strength where the metal is in tension. The centre casting may rest on the top edge of the plated work, and be bolted thereon, or it may fit within all the way down, both designs being common. In either case stiffness of union is ensured by the bolting up.

Castings of this kind must be deeper and stiffer than those which are bolted down on solid masonry, or concrete, due to the difference between the bed that has to be self-sustaining, and the base plate which is reinforced by its supporting area. The beds are not only deep and strongly ribbed, but the metal is thick everywhere. But the error must not be made of unequal or ill-proportioned thicknesses. The boss especially must not be made excessively thick, for if so, fracture will inevitably result in consequence of shrinkage strains. The rest of the work, the wheels and axle bearings, buffers, and various fittings belong to special crane design, rather than to the subject of bed sections.

Crane Drums, or **Crane Barrels**.—These are plain, Fig. 91, 1 and 6; or grooved to carry chain, 2 and 7; or wire rope, 3, 4, 5. Grooving is single, 2 and 7; or right and left hand, 3, 4, 5. Drums are mostly parallel, the exception being the fusee drum, 6 and 7, for derrick cranes, which maintain the load at a uniform height during variations in the radius. Drums are as small as 4 in. diameter, and as large as 8 ft. or 10 ft. They are mostly cast, but in some of large dimensions, for light haulage only, the ends are cast, and the body is of steel plate. Main driving wheels are often attached directly to drums by fitting over the body, 4; or against the ends, 5; or they are on the shaft adjacent, 1. In cheap cranes of small dimensions they are sometimes cast with the drum.

In noting the variations in the bodies of drums, the first is the difference between plain and grooved bodies. The objection to plain surfaces is, Fig. 92, that there is no guidance to cause the chain to lay in even laps, but risk of overriding occurs, so that except in hand and steam cranes of small dimensions grooving is adopted.

There are two kinds of grooves, one as in Fig. 92, where the chain links lie diagonally, with some consequent strain, and that where they lie flat and edgewise alternately. Then if the drum is of large diameter there is practically no bending strain on the short-link chain used. For wire rope, drums are grooved as in Fig. 91, 3, 4, 5, where the rope lies only on the bottom of the groove to prevent chafing of the

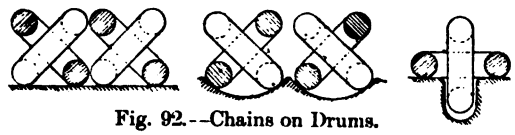


Fig. 92.—Chains on Drums.

edges. Drums are grooved right and left hand in order to maintain a central lift, the rope winding and unwinding from ends to centre, and *vice versa*. The end flanges on grooved drums, which are not really necessary, are now often omitted, as shown in the detail, 2.

The interior is cored, but the cores do not follow the outlines of the grooves, which would involve unnecessary labour. Large barrels are ribbed longitudinally, Fig. 91, 5. Extra metal is left at the ends in the form of external, or internal bosses, 1, 2, 3, to take the shaft keys. The bore at one end is left $\frac{1}{8}$ in. or $\frac{3}{16}$ in. larger than at the other, so that the shaft shall begin to tighten in its holes at both ends simultaneously. It is preferable to key the wheel on the body of the barrel, or to bolt it against ends, as in many of those of large sizes. The reason is to throw the torsional stress on the drum instead of on the much smaller shaft. The largest barrels usually have two wheels, 4, one at each end to equalise the stress. These should have three keys, and the teeth "hit and miss."

Secure attachment of the ropes and chains is essential, and different methods are employed.

An eye bolt A, Fig. 91, 1, put through a lug cast next a flange is a common device, the eye receiving the first link of the chain. Another is to attach a plate, Fig. 93, A, 8, and 11, with an anchor hook, with stud bolts, to receive the chain; or a solid link is fastened into a cored hole in an internal lug, 10. The attachment of wire rope is different. In small drums a lug is used, 9, with a hole tapered larger in the direction away from which the rope leads off, and the end is wedged in this. But in larger sizes the rope passes through the body of the barrel, and is anchored on the side, Fig. 91, 5, A; and Fig. 93, 12, A, opposite to that, B, where it leads off. An eye splice is necessary at the anchored end of the rope.

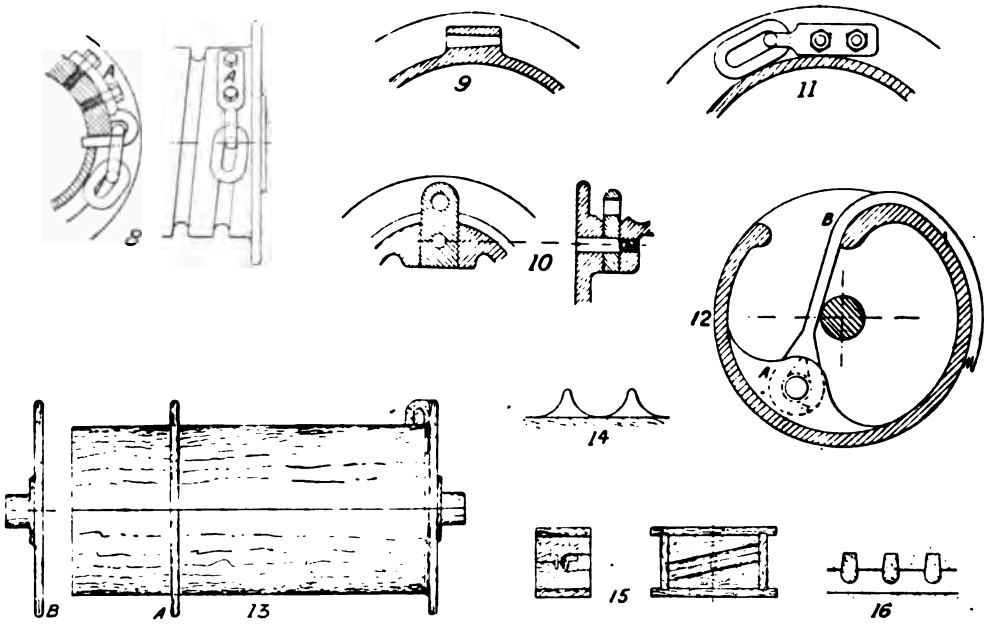


Fig. 93.—Details of Drums.

Methods of Manufacture.—Plain barrels for standard work are cast from patterns of the exact length. For jobbing work a long pattern is used, and a loose body flange, Fig. 93, 13, A, fitted where required, and the end stopped off with flange B. The cores are swept up on a bar, using hay bands and loam. Grooved drums are sometimes made from patterns, but as these are rather expensive, it is often cheaper to cut the grooves in a screw-cutting lathe. Sometimes strips of wood are saw-kerfed, and nailed round, 14, but it is not a good job. The alternative to cutting in the lathe is to sweep up, making a loam pattern for drums up to about 3 ft. 6 in. or 4 ft., and loam moulds over that size. A templet is cut to the counterpart of the profile of the grooved barrel, and the spiral is imparted by sliding this against a templet-screw of the proper pitch wedged on the end of the striking bar. Deep grooves for chains lying flatwise and edgewise are often cored. The prints are nailed on a wood pattern, or swept up on a loam pattern. Fig. 93, 15 and 16, shows the core box and cores inserted.

Crane Ladle.—*See* **Casting Ladle.**

Crane Post, or Pillar.—The central member of a crane around which the superstructure turns. In present day practice in heavy cranes it does not carry the weight of the superstructure, which is taken on rollers, though it does in the smaller sizes. But it is subject to the whole stress due to the overhang of the jib, and the load, tending to snap the post off at the level of its bed, or ground line. Properly, therefore, the post is of parabolic outline; and if of cast iron and hollow, the metal is much

thicker at the above-named zones than at the extremities.

Posts are now mostly made of mild steel forgings, and solid, unless, as is often necessary, a travelling shaft has to come through to drive the truck, or a pipe for steam supply. In all cases the belts have to be turned to fit into the foundation plate, or the truck, and the head also is turned where the top cross girder comes.

In some groups of cranes the post is diminished to a mere pivot, a pin connecting a rotating bed with the truck or the fixed base. These occur in the low type termed horizontal cranes, and in the massive Titan cranes. The strain tending to lift the upper portion of the crane off the lower is taken by the nut on the upper end of the pin.

Stress Calculation for Crane Post.—Crane posts are invariably subjected to bending moments, and are calculated accordingly. Taking an ordinary case of a crane lifting 5 tons at a radius of 18 feet, and fitted with a tail balance of 4 tons at 8 feet radius; the maximum bending moment on the post is found by subtracting the backward moment from the forward one = 5 tons × 18 feet − 4 tons × 8 feet = 58 foot tons = 696 inch tons, net bending moment. Then dividing this by the desired stress, say 5 tons per square inch = $\frac{696}{5}$ = 139 modulus = 11¼ inch diameter. The maximum bending moment and the maximum diameter of post consequently exists at the point where the post enters the main fixed bed plate, or truck bed.

The above calculations are frequently modified by the construction of the crane itself, *e.g.*, the reception of the jib thrust upon a path arranged upon the bed plate. In such cases it is best to calculate the net pull upon the top of the post, and multiply the resulting figure by the distance from the top crosshead to the main bed plate for the bending moment. Such a method has also the advantage of permitting the ready calculation of the post diameter at intermediate points by estimating the corresponding moments.

Crank.—The usual medium through which a reciprocating motion is converted into a rotary one, or *vice versa*.

Cranks are single, or double webbed, the first being used when the connecting rod has to come to one side of the crankshaft, the second where the crankshaft extends to right and left of the rod. The portion embraced by the connecting rod is the *crankpin*. Single-webbed cranks are either of the well-known tapering form, or of the circular, or disc type. Dip cranks are those in which the sides enclosing the pin are forged solidly out of round rod. Webbed cranks are those in which the sides or webs are of rectangular cross section. Both these types are made solidly, the first by bending, the second by slotting or milling through a web sufficiently large. Large webbed cranks are built up; shaft, webs, and pin being separate pieces, turned, bored, and shrunk on, and further secured with sunk keys. Pins in small cranks are variously fastened by parallel and tapered fittings, and riveting. The webs of locomotive cranks are generally bonded, to diminish risk of disaster if fracture should occur. They are made of elliptical shape, or approximately rectangular, with well rounded ends. The cranks of compound engines are counterbalanced by extensions opposite to the pins and webs.

Crank Forging.—Cranks are divisible under web cranks, and dip cranks. The first are slotted, and in large sizes built up, the second have their dips produced by forging. In small sizes, cranks of both kinds are produced wholly in dies, or finished in dies. Dip cranks are frequently made wholly by pressure in dies, for which numerous patents have been taken out from time to time.

The special difficulty about crank forging lies in the webs, which when slotted from the solid involve a good deal of machining; and when bent, in retaining enough metal at the bends. There is a difference too in iron and steel. Webs and pins can be slotted through solid steel, but if slotted in iron the short fibre comes in. Iron is still retained for dip cranks, though largely superseded by steel. When iron is used, scrap, double fagoted is preferable to puddled bars.

Web cranks generally, of which the locomotive crank axle is the familiar type, are made from mild open-hearth steel. A strict test is to pre-

pare test bars machined from the material removed from between the webs. The strength required is from 28 to 32 tons per sq. in., with an elongation of not less than 20 per cent. on 3 in.

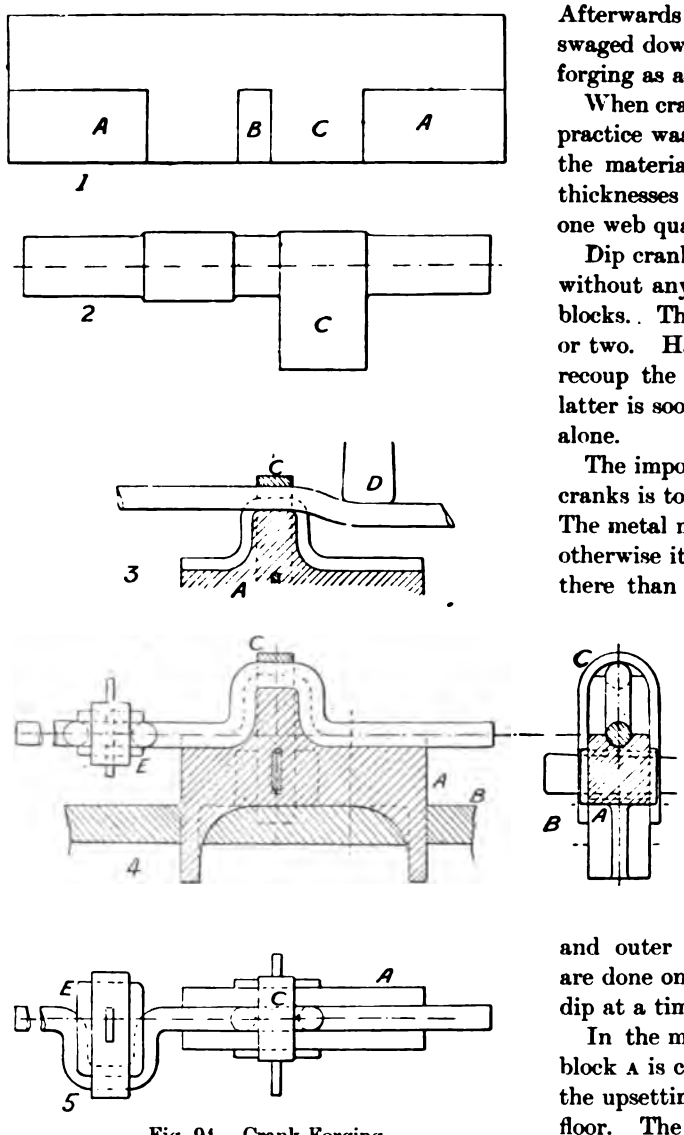


Fig. 94.—Crank Forging.

The crank is made from an ingot, two-thirds of the lower portion only being used. It is forged down to a slab, Fig. 94, 1, the portions AA (gussets) sawn out at the ends, leaving metal to be roughly rounded up for the axle. The portion B between the two webs is slotted or milled out, and the middle roughly rounded. The middle portion is then held between the hammer and tup while one of the web bodies C is turned up to right angles with the first, being gripped with a spanner and moved by power. Afterwards the middle and ends of the axle are swaged down more carefully to size, leaving the forging as at 2.

When cranks were made of iron an occasional practice was to take a straight piece and weld the material for the webs on, in two or three thicknesses each. This avoided the turning of one web quarter round relatively to the other.

Dip cranks are seldom made by hand wholly, without any assistance whatever from bending blocks. This is only justifiable for an odd size or two. Half a dozen all alike are sufficient to recoup the outlay on blocks. The cost of the latter is soon saved in the lessening of tooling alone.

The important point to remember in bending cranks is to have enough material at the bends. The metal must be upset here before bending, otherwise it will draw out and become thinner there than elsewhere. It is upset by taking short heats over the portions to be occupied by the bends, and upending, and jumping on the anvil, or upsetting block—½ in. to 1 in. of enlargement will be necessary.

The first stages of bending, in the absence of special machines, are done by hand. In one method pins are inserted in a swage block, or levelling block, and the bar is pulled and bent to form the inner and outer curves. After this the corrections are done on a block like Fig. 94, 3, 4, 5, A, one dip at a time.

In the method shown in 3, 4, 5, the bending block A is cast. It is carried by the horns in the upsetting block B sunk permanently in the floor. The crank, heated, is cottered down and held with the strap C on the pin portion. Then one side of the dip is bent by blows from a suspended monkey D, and afterwards brought round to a fair bedding by the swinging monkey striking against the end of the bar. The sledge and swage afterwards complete the fitting all along that side of the crank and axle, and into

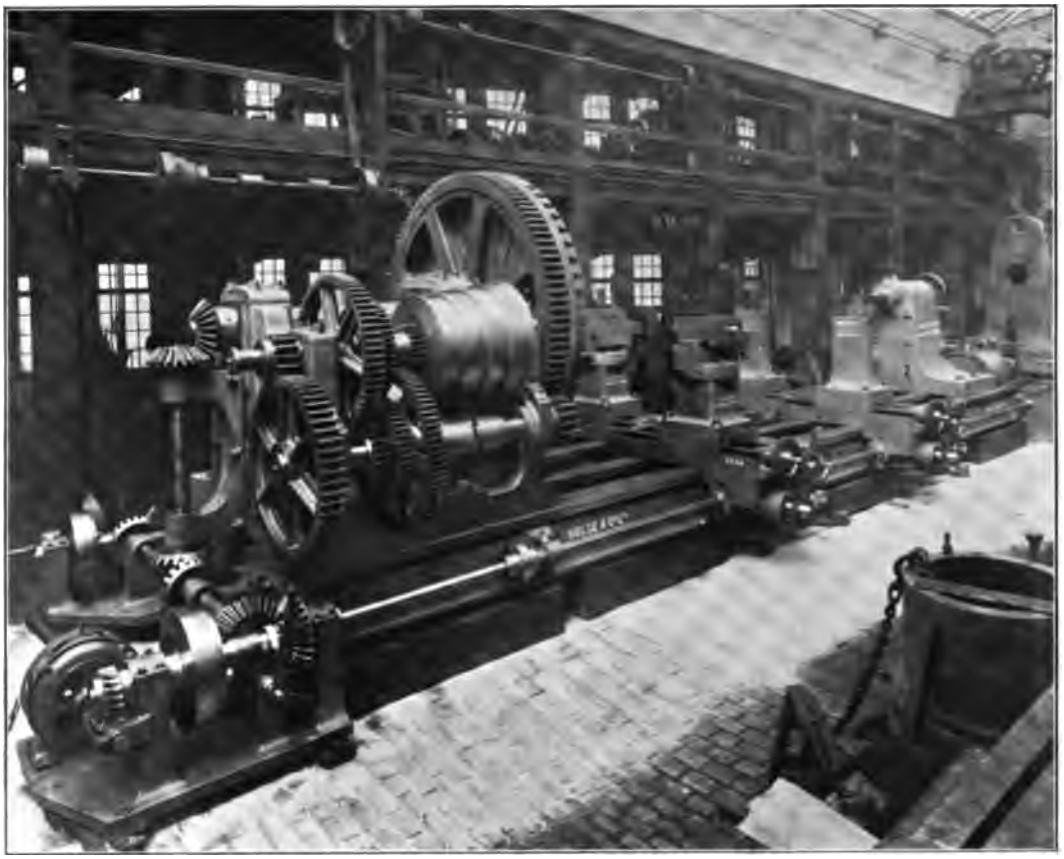


Fig. 96.—Crankshaft Lathe, Belt-Driven and with Electric Motor for Quick Traverse of Rests. (Hulse & Co., Ltd.)

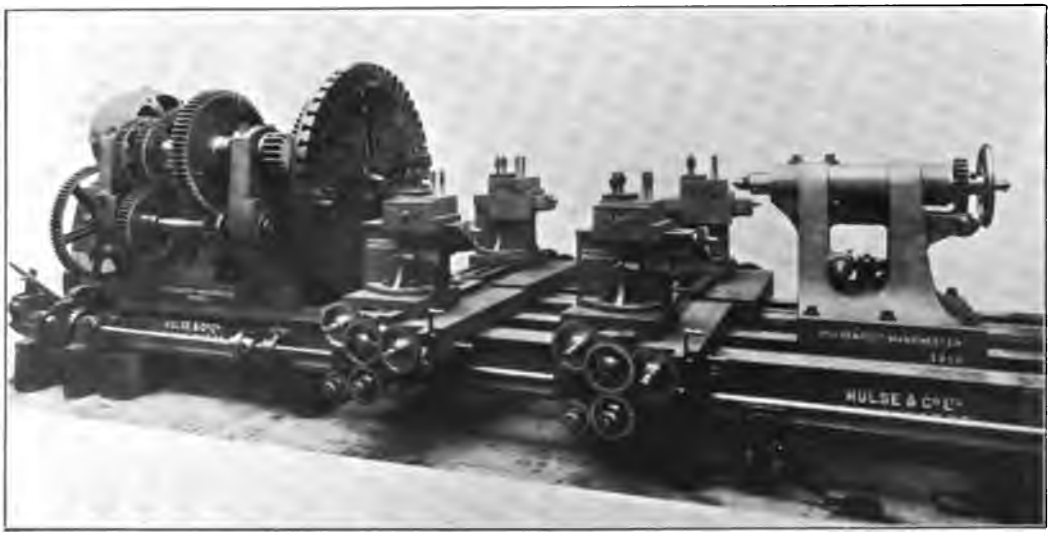


Fig. 97.—Motor-Driven Crankshaft Lathe. (Hulse & Co., Ltd.)

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the curved portion of the block. Afterwards the crank must be uncottered, and another heat taken to treat the other side similarly. The same operations have to be gone through for each dip in two-throw, and three-throw cranks. While these are being done, the finished dip or

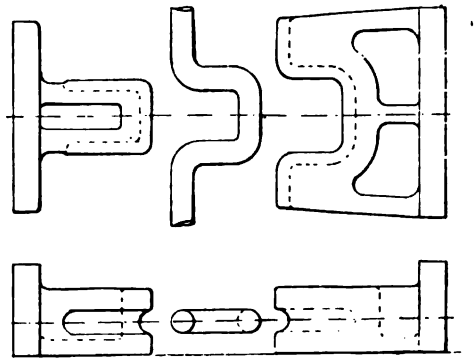


Fig. 95.—Crank Forging.

dips are retained by the insertion of a block like Fig. 94, E, with its strap and cotter.

Fig. 95 shows a pair of dies used for bending cranks of this kind in a press.

Crankshaft Lathe.—The massiveness of marine and other crankshafts demands special lathes for turning the throws and parallel portions; these differ mainly from ordinary shafting lathes in greater relative height of centres, as well as in the provision of two narrow rests, adapted for passing between the sides of webs, instead of having to use long tool holders overhanging excessively. A large face-plate is fitted, so that massive counterweights may be bolted on to balance the throws and prevent irregular running.

Two examples of crankshaft lathes are seen in Figs. 96 and 97, Plate VII. Fig. 96 is driven by belt from an overhead motor-driven countershaft, while a smaller motor on the floor effects quick power traverse of the carriages when adjusting. The four carriages can be operated simultaneously, or at differing rates. The headstock is quadruple geared, having thirty-two speed changes, uniformly graduated. The total weight is 98 tons.

Fig. 97 illustrates a motor-driven design, the power of which may be gauged from the fact that it absorbs 90 HP. when cutting. The variable speed motor, combined with the gear changes, affords a large number of speeds. An independent constant speed motor is fitted for traversing the carriages quickly along the bed. The loose poppet arrangements in both of these lathes comprise a hand gear for racking the poppet along the bed, a worm gear for forcing the barrel and centre up to the work, and a plain handwheel for rapid movement of the barrel, when effecting adjustments. A special feature of the lathes consists in the non-rotating twin screws, these being fixed in bearings, while the nuts are revolved around them to move the carriages along, a device which possesses many advantages. Each carriage is provided with its own reversing gear, so that it may be moved to right or left, without reference to the others. The screws may be made in two pieces in those of great length, thus facilitating construction and transport. Both lathes shown have screws lying within each shear of the beds, so that each rest is propelled by an effort applied directly under the tool.

Lathes of this type are in use by the leading marine and engine firms; an interesting point is that the same class of lathe has been adopted for turning the rotors of large marine turbines.

Crank Turning.—To turn cranks requires several chuckings, and various precautions.

In the first chucking the axle is turned. But a preliminary roughing down of the pins and web is generally advisable before any part is finished to dimensions, because spring is liable to occur on the removal of the skin. In webbed cranks preliminary sawing out, or milling, or slotting out of the web spaces has to be done before turning.

Crank turning is a job that commonly requires the assistance of chucking plates, in which the throw is embodied. The plates are sometimes forged on the ends of stamped cranks, Fig. 98, 1, and cut off after the turning is done, but in other cases they are separate. In Fig. 98, 2 and 3, they are clamped on the ends of the crank by means of a bolt through a split lug. A single-throw crank need only have one chucking centre, as in 1; in a double-throw, 3, two centres are fixed 90° apart; the plate employed for 2 is a two-throw plate utilised; in a three-throw, Fig. 99, there are three centres at 120° apart.

Of course either one of these plates can be used for single-throw cranks, using one centre only.

As the edges of webbed cranks have to be turned for good appearance, another set of

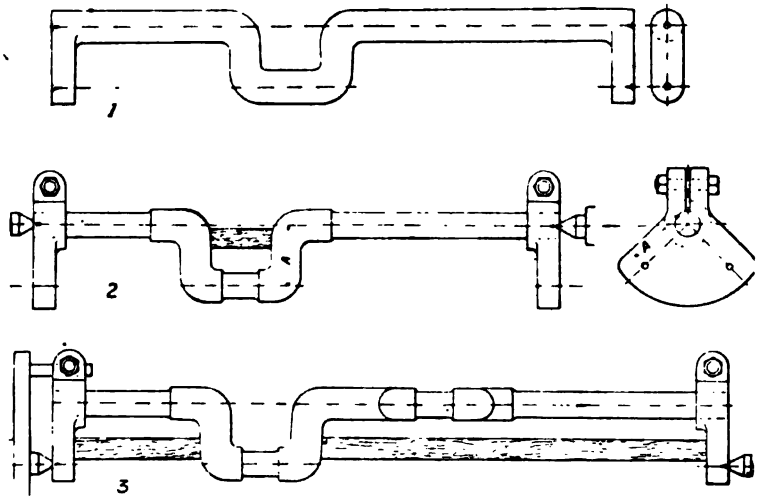


Fig. 98.—Crank Turning.

centres is included in the plate, Fig. 99, for chucking for these.

When fixing the plates on the crank ends, the axle portion is laid on tall vee blocks on a marking-off table, or machine bed, and the alignment of the centres of the crank pins in the rough forging, and of the corresponding centres on the chucking plates is set by square and surface gauge, after which the split lugs are securely tightened. If there is any doubt about the pins holding up to size, a preliminary chucking should be made on each centre, and a slight surface cut taken.

When turning the axle and pins the thrust of the lathe centres takes place away from the solid metal which could resist it, and the crank would spring unless strutted. This is done with a bar of wood or of metal. Fig. 98, 2, shows a strut used between the dip during turning of the axle; Fig. 98, 3, two struts between the dip and crank plates, while turning the pin, and Fig. 99 illustrates two alternatives for strutting the dips while the axle and outer web faces and edges are being turned. In one case bolts are used, and turning the nuts as though to run them off, tightens the bolts against the web faces. In the other, shown at A, two clamping plates are shouldered to fit on the edges and between the inner faces of the webs, and being clamped by the bolt, prevent any spring taking place either longitudinally or of a torsional kind. Though the bolts are shown in all the dips in Fig. 99, it is of course understood that each must be removed from its place when that particular pin is being turned.

Another difficulty is that of spring circularly in light cranks, and this is met by the use of a special form of steady having a rotating disc moving round with the axle during the turning of the pins. The axle passes through a bearing in a slot in the disc. During the turning of the axle any ordinary lathe steady can be used.

Driving takes place from a small angle plate on the face plate, against the edge of the

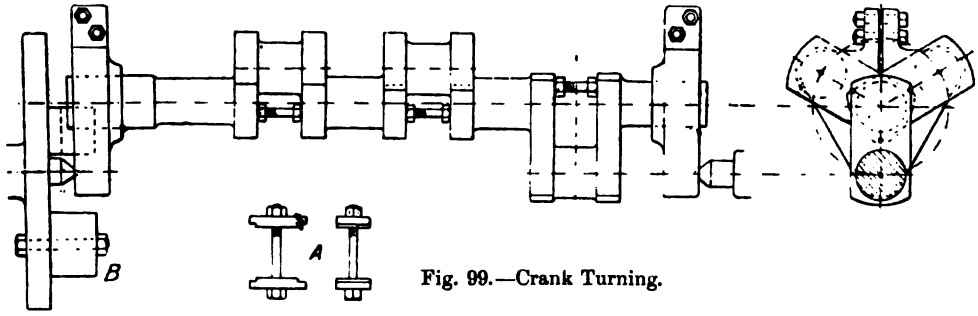


Fig. 99.—Crank Turning.

chucking plate. The mass of these is counterbalanced by a weight bolted to the face plate, Fig. 99, B, or clamped on the axle.

Creeping. — The difference between the rate of revolution of driving and driven pulleys, owing to elasticity and slip in the belts or ropes. Applies also to the mysterious longitudinal movements of railway rails, the reasons for which have never been satisfactorily explained.

Creosote, Creosoting (Gr. *kreos*, flesh, and *soter*, a preserver).—Is obtained by the distillation of wood or coal tar. It is an oily strong smelling liquid used mainly for the preservation of timber. Owing to its powerful smell, creosoted timber cannot be used in dwellings, but is of immense value for railway sleepers, paving blocks, piles, ties, &c. All timber requires, however, to be well seasoned before saturation with creosote, otherwise decay begins in the interior of the wood where sap remains. Timber of irregular density, like spruce, is least suitable for creosoting. From 8 to 12 lb. of creosote oil are required per cubic foot of timber. The operation is performed in a long cylindrical chamber of wrought iron, or steel, opening at one end only. Balks of timber are run in on a trolley along rails laid on the floor of the chamber, the door is closed, and a partial vacuum created to extract the air and moisture contained in the pores of the timber. Creosote then flows in hot, and enters the fibres of the wood under a pressure of about 170 lb. per square inch, the balks being chained down to prevent them rising to the roof of the chamber. Fig. 100, Plate VIII., shows a complete creosoting plant, the cylinder and carriage being seen on the right. The arrangement of the various portions is not as when at work, but only as erected in the makers' shops. The boiler is on the left and the engine and pumps in the centre. The arrangement of hoops around the timber on the carriage will be noted, as well as the little crane for handling the end door or cover.

Crib Work.—A method of building jetties in Canada and the United States. A box is framed together with balks; floated over the area of the jetty, and weighted with stone to sink it, and filled up. After settlement the cribs are wedged up, and planks laid on them to form the roadway.

Critical Speed.—A revolving body rotating at increasingly high speeds will eventually reach a certain speed at which excessive vibration will occur, and this is termed the critical speed. It is believed to be due to a change in the axis of rotation, consequent on the bending of the shaft, so that the shaft and the wheel or other body which it carries no longer rotate about an axis which corresponds with the centre of gravity, but around a new axis—the axis of deflection.

Crocodile Shears.—Crocodile or alligator shears and squeezers are used in the manufacture of puddled bars.

Crocus.—One of the polishing compositions used for fine work, being an oxide of iron of a red colour.

Crook-Bit Tongs.—*See* **Smiths' Tools.**

Crop Ends.—The extreme ends of bars and sections which are shorn or sawn off by various cropping machines.

Cross.—Denotes the St Andrew's cross used in foundries for lifting and turning over large moulds, but specially for hoisting loam moulds that require four points of support. These are carried in slings suspended from the arms of the cross. The term is also applied to a wrought-iron pipe connection of that form. Cross bracing signifies counterbracing. A cross-cut chisel is a form of **Chipping Chisel.** For crossed belt *see* **Belting.** Crossed rods signify the position of eccentric rods relatively to the slot link and the eccentric sheaves. If when the centres of the sheaves are between the axle and the link, the rods cross, this term is applicable, but if they do not cross the rods are said to be open. Cross grain signifies crooked curly grain in timber, and cross-way of the grain the section taken along the fibres in malleable iron. A crosshead is the element of union between the piston, connecting rod, and slide blocks of engines or pumps. It is also a term of frequent application to various transverse members, such as the beam of an hydraulic press, or moulding machine, or the head of an accumulator ram, or the end of a wheel press, &c. A cross section is a transverse section. Cross slides carry the tool boxes of metal planing machines, the cut-off and forming tools of automatic screw machines, and capstan lathes, and

the surfacing tools of common lathes. Cross tubes are the water tubes of vertical boilers.

Crossed Arm Governor.—In the ordinary Watt governor the height of the rotating pendulum is measured from the centre of gravity of the pendulum to the point of suspension, which is correctly, not necessarily, the suspension pin, but the point of intersection of the pendulum arm with the central spindle. Since the suspension pin is usually on the same side of the central spindle as the weighted arm, it follows that as the ball rises when the arms fly outwards, the true point of suspension comes down, and the height of the governor is reduced more quickly than if the arms were actually pivoted on the centre line. Thus for any accession of speed demanding a change of

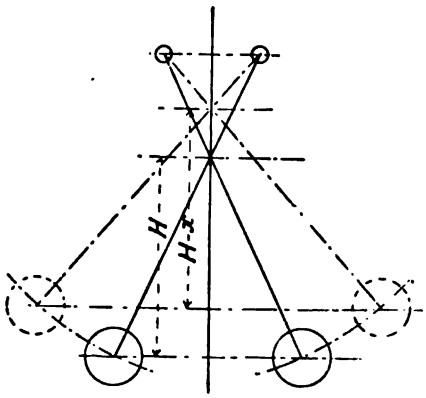


Fig. 101.—Crossed Arm Governor.

height from H to H-x, the movement of the balls must be less in the absence of central suspension, and the power of the governor will be less. If, however, the arms are carried across the central spindle, and hung on a point opposite from the balls, the governor is said to be crossed, and as the balls rise so also does the real suspension point or point of intersection of the arms on the spindle, Fig. 101.

In order to increase or decrease the height of such a governor, the vertical movement of the balls must be *greater* than with the central suspension, because the true suspension points move up and down as the balls move up and down. The governor becomes more powerful because the balls move through a larger arc for a given change of speed. This more potent action is the greater according as the suspension pin is the further removed from the central spindle, and is the more potent when the pendulums are near their lower position. As the balls fly further out their rise for any difference of angle increases in a greater ratio than the rise of the virtual point of suspension. In the figure, H and H-x, they do not differ much, but they would differ considerably if the angle of the pendulums were increased. The crossing of the arms when suitably proportioned produces an approximation to the parabolic governor. *See* **Governors, Parabolic Governor, Isochronous Governor.**

Cross-cut Saw.—Owing to the fibrous nature of timber, it is necessary to have two classes of saws for cutting it: one for "ripping" with the fibres or grain, and the other for cutting across the grain. The latter are called cross-cut saws. They have smaller teeth, with more set, and less rake or hook than saws for ripping. Most of the saws commonly used for hand work are more or less distinctly of the cross-cut type, because generally it is more convenient to do ripping at a machine saw. The ordinary hand saw is intended primarily for cross-cutting. Cross-cut circular saws are frequently used, and unless separate machines are kept, have to be put on when the work requires it; the ordinary circular being taken off the spindle and the cross-cut saw put on.

There is one kind of saw, however, that is called specifically a cross-cut, and unless the term is otherwise qualified it is understood that this is meant. It is a large saw, with a handle at each end, and is worked by two men. It is wider in the middle than at the ends; its back being straight, but its tooth line curved or bellied. Its teeth have no rake either way, or have negative rake, and consequently cut the same in both directions. Cross-cut saws that cut only in one direction always have some amount of rake given to their teeth, and are therefore not at the extreme of the cross-cut type. The large cross-cut saw is nearly always of the shape described, with two handles; but another form, with one handle and a tapering blade, is made, though less used, and requiring to be mentioned as a one-handled cross-cut to distinguish it from the ordinary form. These saws

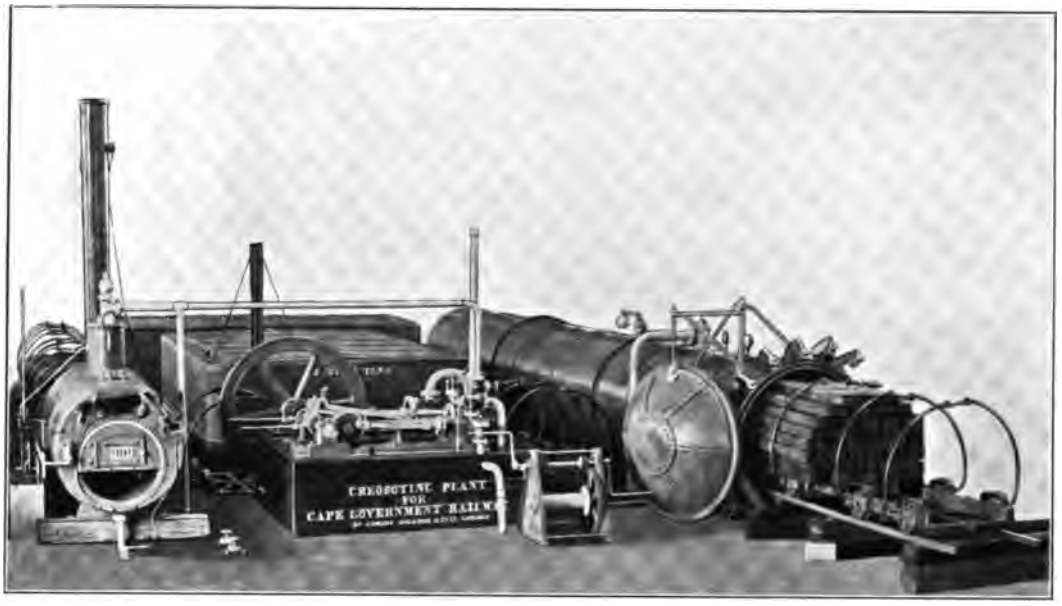


Fig. 100.—Creosoting Plant, Showing Cylinder and Timbers on Extreme Right.
(Cowans, Sheldon, & Co., Ltd.)

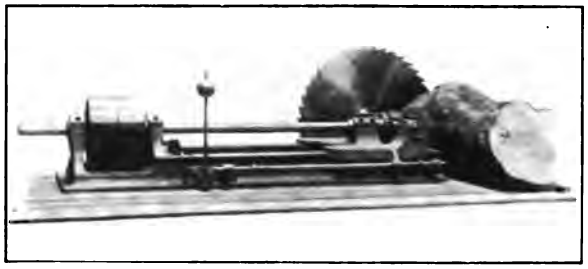


Fig. 102.—Cross-Cut Saw for Logs.



Fig. 103.—Cross-Cut Saw for Boards.
(Thos. Robinson & Son, Ltd.)

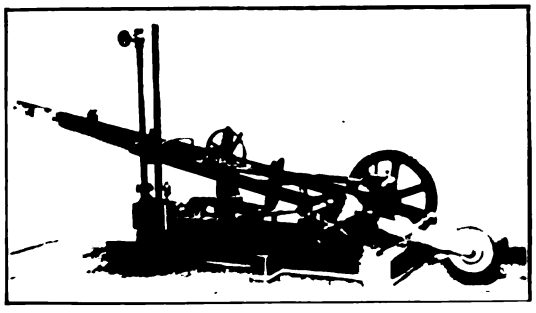


Fig. 104.—Reciprocating Cross-Cut Saw.
(Thos. Robinson & Son, Ltd.)

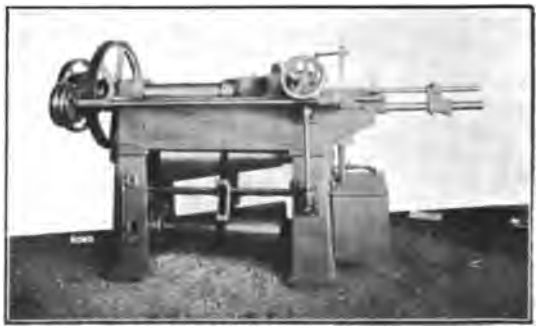


Fig. 109.—Cutting-off Machine with Increase-Speed Device. (The Pratt & Whitney Co.)

To face page 96.

are used for cross-cutting balks, beams, trunks, and any large pieces of timber that are too thick to be cut expeditiously with an ordinary hand saw. Besides having no rake there is sometimes a peculiar form, called "lightning tooth," given to the teeth of these saws. It consists in having the teeth in series of three comparatively small points, with very deep gullets or spaces between each three.

Examples of cross-cut saws are seen in Figs. 102-104, Plate VIII. Fig. 102 is for trees and logs, taking saws up to 6 ft. 6 in. diameter, and running at 450 revolutions per minute. A different pattern is seen in Fig. 103, for cutting boards, the latter being laid on the travelling table, running with rollers on the vee-ways. Fig. 104 is a reciprocating type, employed for work on large logs. Driving is done by a small self-contained steam engine, so rendering the machine independent. The cut is taken on the inward stroke, so that the blade is kept taut while cutting.

Crowd Weights. — The concentrated weights per unit area of a floor, estimated on the supposition that the loading is as close as it is possible to be.

Crown. — Denotes the top of a vertical boiler, both of the shell, and furnace; also the commonest quality of wrought-iron plate; and a bevel wheel standing on a vertical shaft, teeth upwards.

Crow's-Feet.—The vee-shaped ticks on drawings which indicate the termination of dimension lines.

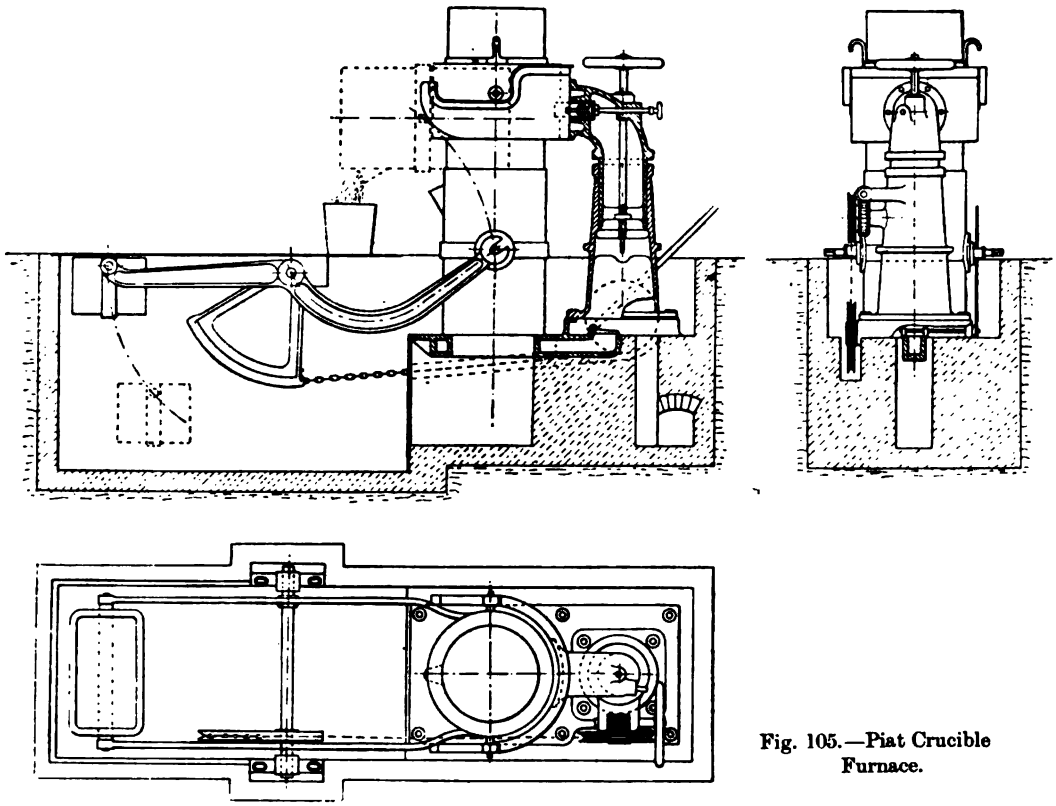


Fig. 105.—Piat Crucible Furnace.

Crucible Furnaces. — Any furnaces in which metals or alloys are melted in crucibles. They therefore embrace a large number of designs; from the furnaces used for the first melting of blister steel to those employed for steel casting, for brass, and gun-metal, aluminium, copper, gold, silver, &c.; and heated by coke, or gas, by natural or forced draught. They also include single furnaces taking one crucible, and furnaces in series to receive a large number.

The crucible furnace of the steel melters comprises essentially a "melting hole" or chamber, measuring about 3 ft. deep, and from 1½ to 2 ft. square, lined with brick and ganister. This is sunk in the floor, the ashpit being below, and communicating with a vault through which the ashes are removed. The resemblance is thus apparent to a battery of brass-melting furnaces. Each melting hole is connected by a flue to a chimney stack. The draught can be regulated from the vault through an opening which communicates with the chimney, being extra to those coming from the melting holes.

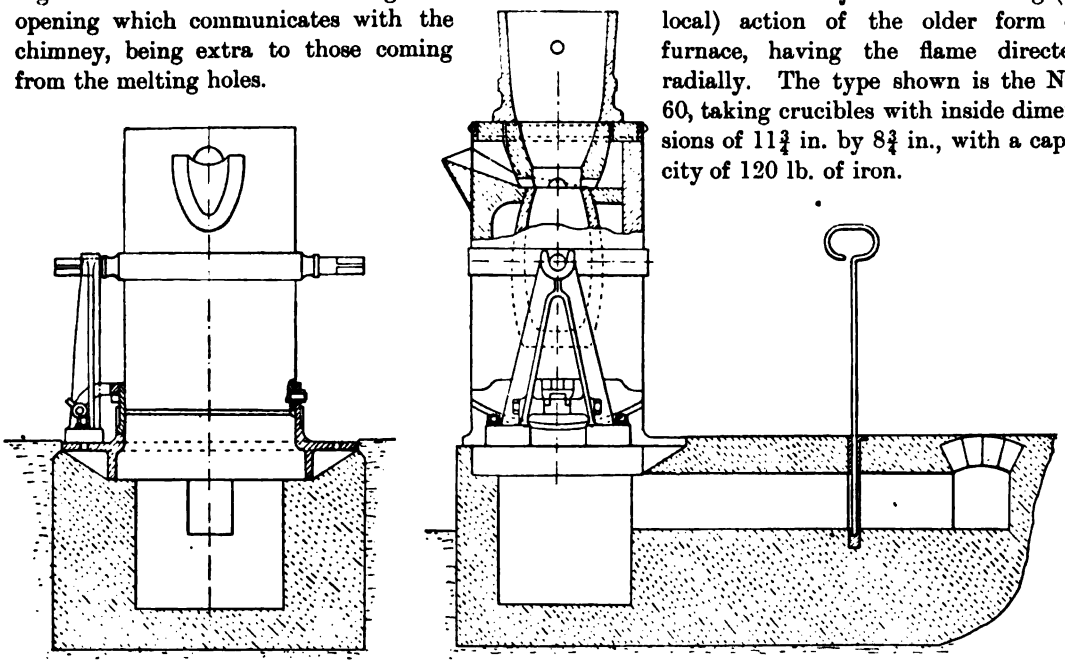


Fig. 106.—Piat Crucible Furnace.

The furnaces by A. Piat & ses Fils, illustrated, Figs. 105, 106, are designed with the object of retaining the crucible in the furnace constantly, in preference to the usual practice of lifting it in and out with tongs. The idea is that the crucible will be less liable to injury by frequent handling, and draughts. The furnace is therefore hinged on a lever actuated with a quadrant rack and pinion, moved by a hand-wheel above the foot-plate (Fig. 105). The crucible is enclosed in a brick-lined furnace, and the latter is surmounted with a hopper crucible (Fig. 106), by which the metal is fed into the furnace, and in which it is heated before it is poured. The heat wasted in ordinary furnaces is there utilised. The Piat furnaces are blast furnaces, the blast being brought in at the bottom. The crucibles last on an average from 60 to 80 heats. The fuel consumption is from 14 to 20 per cent. that of the weight of metal, if the furnace is kept in continuous operation.

Another type of a furnace, gas fired, is shown in Fig. 107, by Fletcher, Russell, & Co., Ltd. The flame enters the furnace at a tangent, as seen in the plan view, the idea of this being to avoid the objectionable cutting (or local) action of the older form of furnace, having the flame directed radially. The type shown is the No. 60, taking crucibles with inside dimensions of 11¾ in. by 8¾ in., with a capacity of 120 lb. of iron.

Crucible Cast Steel.—Steel, which being produced first by the cementation process, is melted in a crucible for the purpose of rendering it homogeneous. The blister steel is not sufficiently so for tools, and articles requiring absolute uniformity in texture. The practice dates from 1740, when Huntsman introduced it into Sheffield. Foreign substances are generally included, as manganese, or speigeleisen, or bar iron; or puddled steel or mild steels are often melted in crucibles along with the above substances for the production of cheaper qualities of cast steel. Crucible cast steel is used on the largest scale at the Krupp works, where the product of several hundred

crucibles is often used for the casting of a large gun.

Crucible cast steel is made either (1) from selected blister steel, melted simply; (2) from

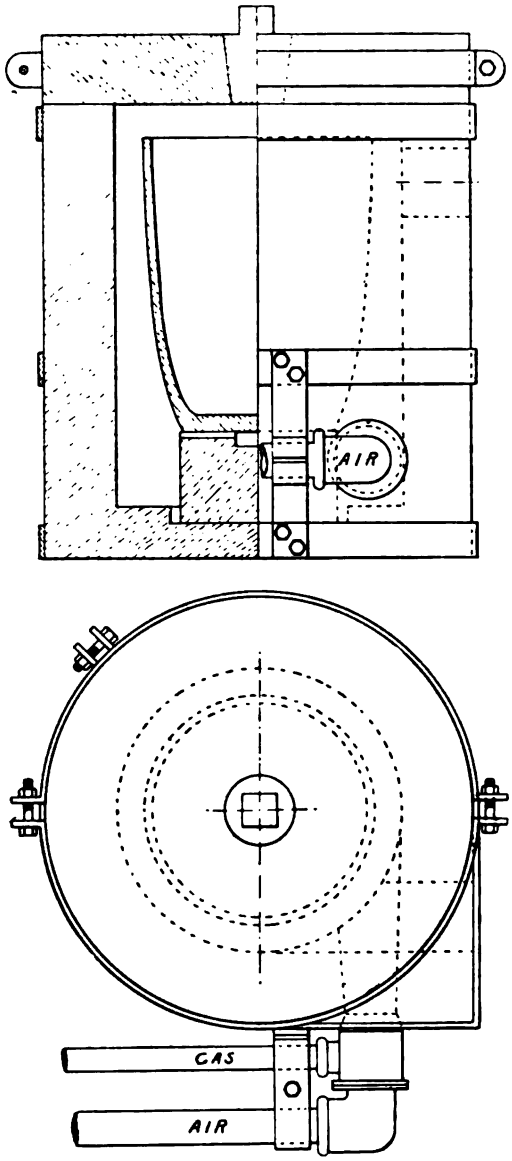


Fig. 107.—Fletcher Crucible Furnace.

blister steel of hard temper melted with mild scrap, by which the temper is let down to that required; (3) by melting unconverted Swedish bar iron; which is cut up, and melted with charcoal; (4) by melting pure pig iron with bar iron; (5) by melting malleable scrap iron with charcoal and oxide of manganese (Mushet's process); (6) by melting Bessemer or Siemens steel.

Crucibles.— The crucibles used for steel melting are still generally made of clay, though graphite crucibles are sometimes employed when a mild steel is melted for the production of crucible cast steel, the graphite in the pots combining with the spiegeleisen added to produce the temper required. The crucibles are made in the steel works, and a small quantity of ground coke and old pots is often added. The materials are finely ground, and kneaded, and moulded in an iron flask, using a plug driven with a mallet to form the interior. The top is closed in subsequently, and a long period of drying follows, lasting from a fortnight to six weeks. The moulding is done both by hand and by machine. When plumbago crucibles are used, Ceylon graphite is mixed with fire-clay. They last longer than those of clay, and are almost invariably employed for melting the brass and bronze alloys.

Crucibles must be annealed before use, to prevent risk of their cracking. They are placed over the mouths of the furnaces, or in a place in the chimney for several hours. They are warmed up also just previous to use, being set mouth downwards on the fire when first lit, or on the cover of a furnace in work. The reason why these precautions are necessary is the absorption of moisture by the porous material, and which unless driven off would cause flaking and cracking. In damp weather this warming up is more essential than in dry. Crucibles are stored in a dry place, generally on a shelf above the row of furnaces.

Crystallisation.—*See* **Crystallography.**

Crystallography.—When a substance passes from the liquid or the gaseous into a solid state it very frequently assumes a geometrical form, and these geometrical forms are called crystals. (If, on the other hand, the solid has no definite geometrical shape, like glue, it is said to be amorphous.) Molten iron on cooling to cast iron becomes crystallised; salt, soda, and alum are all crystalline forms, obtained from their solutions in water. Many rocks and metals are found in a crystalline condition, formed in most cases when cooling in the earth. When the

cooling process is a gradual one the crystals are larger and more perfect than when the change occurs rapidly.

Crystals may be formed by (*a*) fusion, (*b*) solution, (*c*) sublimation, (*d*) electrolysis. The formation of crystals by *fusion* (as in the melting and subsequent solidification of metals) is commonly seen in engineering. Commercially, crystals are obtained from *solution*. They are either thrown down as a hot saturated solution cools, or as the solvent is evaporated, by artificial or natural means. Crystallisation is thus a means of purification. Crystals are formed by *sublimation* when a substance, acted on by heat, passes off as a vapour, and this vapour is condensed on a cold surface. Iodine is an example. Finally some metals are deposited as crystals at the negative pole in *electrolysis*.

In some cases the same substance may crystallise in different forms, but on examination it is found that however different the forms may be, *the angles between the faces are always constant*. This is one of the most striking laws of crystallography. In order to group and classify the various crystalline forms, three or four "axes" are imagined to pass through the body of the crystal, all crossing in its centre, and passing through the crystal from one side to the other. The seemingly countless forms of crystals are thus reduced to six systems.

1. The *regular*, cubic, or isometric system. In this the three axes are all equal, and cut one another at right angles. The cube is the simplest form of crystals comprised in this system. The rhombic dodecahedron and the regular octahedron are also common forms. The crystals of fluor spar, iron pyrites, and the diamond belong to this system.

2. The *hexagonal* or rhombohedral system, with three equal axes in one plane cutting one another at 60°, and a fourth axis (longer or shorter than the others) cutting the plane of the other three at 90°. The principal forms here are the six-sided prism, and the double six-sided pyramid. Quartz, calc-spar, and graphite crystallise in this system.

3. The *quadratic* or tetragonal system. In this three axes cut one another at right angles, but one axis is longer or shorter than the other two. Tin dioxide belongs to this system. (This is sometimes called the square prismatic system.)

4. The *rhombic* system, in which three unequal axes cut one another at right angles. Native sulphur, nitre, and arragonite crystallise in this system. (Sometimes called the right prismatic system.)

5. The *monoclinic* system, with three unequal axes, two cutting each other obliquely, and the third cutting the plane of the other two at 90°. Sulphur (from fusion), and ferrous sulphate, are among the numerous substances which assume this form on crystallising. (Sometimes called the oblique prismatic system.)

6. The *triclinic* system. In this, three unequal axes cut one another obliquely. Copper sulphate is the commonest substance which assumes this form.

In many cases the same substance crystallises in different forms belonging to the same system. Some, however, have the peculiar property of crystallising in more than one system. These substances are called *dimorphous*. Carbon, silica, and sulphur are examples. Other substances again are *isomorphous*, that is, they crystallise in identical forms and possess analogous chemical composition. The crystallisation of isomorphous substances thus frequently gives important clues as to the constitution of a compound, and a comparison of two isomorphous substances makes it possible to check or even to discover the atomic weights of one of the elements in combination.

Cube.—1. A cube is a solid bounded by six equal surfaces, each of which is a square. It is a particular case of a rectangular parallelopiped. *See* **Parallelopiped.** Length, breadth, and depth being alike, the rule for finding the contents of a cube becomes:—

$$\text{Volume} = \text{length}^3.$$

The following rules are useful in certain cases:—

Volume = 1·909 × vol. of inscribed sphere.
Volume = 1·273 × vol. of inscribed cylinder.
Volume = 3·819 × vol. of inscribed cone.

If the volume be given and the length of the edge be required:—

$$\text{Length} = \sqrt[3]{\text{volume}}.$$

(*See* **Cube Root.**) The diagonal may also be

calculated by multiplying the length of an edge by the square root of 3 :—

Diagonal of cube = 1·732 × length.

The total surface area of a cube is the sum of the areas of the six faces, *i.e.*, six times the area of one face, and the area of one face is the square of its side. Therefore the rule becomes:—

Surface area = 6 × length^2.

2. The cube is one of the simplest forms of the first system of **Crystallography.**

3. In arithmetic the cube of a number is the product obtained by multiplying it by itself three times. Thus the cube of $7 = 7 \times 7 \times 7 = 343$.

4. The centre of gravity of a cube coincides with its centre of mass, *i.e.*, the middle point of a line joining the points of intersection of the two diagonals of two opposite faces.

Cube Root.—The cube root of any given number is that number which, when multiplied by itself three times will produce the given number. Thus the cube root of 27 is 3, for $3 \times 3 \times 3 = 27$. The cube root of a number, say 27, is denoted generally as $\sqrt[3]{27}$, but sometimes as $27^{\frac{1}{3}}$. Tables giving cube roots of numbers are included in many engineering pocket-books, but it is often useful to be able to calculate them. Sometimes this can be done by splitting up the number into factors. Thus $729 = 9 \times 81 = 9 \times 9 \times 9$, and therefore $\sqrt[3]{729} = 9$. This, of course, is not possible with big numbers, and recourse must then be had to the following method.

To find the cube root of 17,576 :—

	17'576(26
$2^3 = 8$	
$300 \times 2^2 = 1200$	9576
$300 \times 2^2 \times 6 = 7200$	
$30 \times 2 \times 6^2 = 2160$	
$6^3 = 216$	
9576	9576

Beginning with the right-hand figure, mark off the number in groups or periods of three. Find the biggest number whose cube is contained in 17 (*i.e.*, 2), put this in the quotient and subtract its cube, $2 \times 2 \times 2 = 8$ from 17. Bring down the next group of figures. To find the second figure of the root, the first figure, 2 is squared, and multiplied by 300. This gives 1,200, which is then divided into 9,576 to give some idea of the second figure of the root. 1,200 goes 7 times into 9,576, but this would be found too great, and so the lower number, 6, is taken. (It is very often necessary to reject a number thus found for a lower one.) We are, moreover, strongly led to suspect that 6 is the correct number, because $6 \times 6 \times 6 = 216$, and the units' figure of this latter number, 6, is the same as the units' figure of the dividend (9,576). The total, 9,576, is got by adding up :—

$300 \times$ (number found)$^2 \times$ (new figure),
$30 \times$ (number found) $\times$ (new figure)^2,
(new figure)^3.

In this particular case the number found is 2, and the new figure is 6. Here is another example :—

	13'044'257'864(2354
$2^3 = 8$	
$300 \times 2^2 = 1200$	5044
$300 \times 2^2 \times 3 = 3600$	
$30 \times 2 \times 3^2 = 540$	
$3^3 = 27$	
4167	4167
$300 \times 23^2 = 158700$	877257
$300 \times 23^2 \times 5 = 793500$	
$30 \times 23 \times 5^2 = 17250$	
$5^3 = 125$	
810875	810875
$300 \times 235^2 = 16567500$	66382864
$300 \times 235^2 \times 4 = 66270000$	
$30 \times 235 \times 4^2 = 112800$	
$4^3 = 64$	
66382864	66382864

Whenever the trial divisor is greater than the number to be divided, a nought is put in the quotient, and the next group of figures brought down.

Where decimals are included in the number the figures are marked off in three's to the right and left, beginning with the unit figure. Thus, 64'392·163'241'6 ; ·453'216'7 ; and if the decimal does not contain three figures like ·74 a cipher may be added without of course altering the value ·740.

The cube root of a fraction is found by taking the root of numerator and denominator separately, $\sqrt[3]{\frac{8}{125}} = \frac{2}{5}$. But if they are not perfect cubes the fraction must be brought to a decimal, and the root then found by the ordinary method. (The process of bringing a

vulgar to a decimal fraction is explained under **Fractions**.)

The sixth root of a number is found by taking the square root of the cube root.

Cultivator.—*See* **Plough.**

Cup Chuck.—Another name for the **Bell Chuck.**

Cup Leathers.—*See* **Hydraulic Leathers.**

Cupola.—The melting furnace of the iron foundry. It derives its name from a feature which is not often present, the covered-in top. Cupolas are built with shells of boiler plate riveted together, lined with fire-brick, and daubed each day, or before each melting, with fire-clay.

Cupolas vary in type as follows:—They may have solid, or drop bottoms, may have two, or three tuyere pipes entering directly; or discharging into a wind chest. They may have fixed, or shifting tuyeres. The top may be open, or closed, and the metal may be tapped direct, or pass through a receiver. Variations occur in proportion of height to diameter, in the number, and areas, and height of tuyeres; in height of charging door; in methods of working: as in blast pressure, proportion of bed charge, rate, and ratio of melting, and quality of metal brought down, &c.

The holes in a cupola are: the tap hole at one side, the slagging hole at the other, the tuyere, and sight holes, and the charging door. The tap hole is closed with a bit of clay, and when it is pierced the metal runs down a shoot into the ladle. The slagging hole is closed with a piece of plate, and a bridge bar.

The principal interest in cupolas centres in the tuyere arrangements, and the actual charging, and melting.

When blast pipes discharge directly into the cupola they are fitted to swivel in their sockets, so that the furnaceman shall be able to insert a bar to clear away any accumulations of slag from the vicinity of the tuyeres. The air belt, or wind chest is the alternative, which is used on nearly all large cupolas, or those say of over about 4 feet in diameter. Its advantage is the more equable distribution of the blast. The details of the arrangements of the tuyere holes vary. Generally it is considered better to have two or more rows in different zones than one only. Several patents have been taken out at intervals bearing on this detail.

A third type is the centre blast, in which the blast is brought up through the bottom of the cupola in the centre and distributed. The idea was, that a more equal diffusion of air was obtainable, but the design has not been adopted to any great extent.

There is no hard and fast rule for the height of tuyeres. They would be higher than they are, but for the fact that the bed charge would have to be deeper. High tuyeres are favourable to a large reserve of heat in the melting zone, more room for slag, and for metal to accumulate. About 10 in. or 12 in. is a suitable distance from the bed of the cupola to the bottom of the tuyeres, and the bed charge may reach from 14 in. to 16 in. above the top of the tuyeres. The drop bottom has the advantage over the solid brick bottom that the clinkers can be dropped at once after a blow, instead of raking them out through the breast hole.

Statements made as to the percentages of fuel used in melting iron are often misleading, owing to the difference in the conditions of melting; such as size of cupola, duration of blow, delays between tapping, the fluidity of the melted iron, the kinds of iron used, &c. Experiments on the relative economy of melting should either be conducted in the same cupola, or in cupolas of similar capacity and doing similar work.

A small cupola requires a greater percentage of fuel than one of larger size. The longer a cupola is running the smaller the percentage of fuel required, because the cost of the bed charge is spread over a larger total of castings, and the cupola retains its heat without the sacrifice of fuel for that purpose.

More fuel is required for melting heavy than light scrap. The consumption of fuel in cupolas will range anywhere between about 1½ cwt. to 3 or 4 cwt. per ton of iron melted, always, of course, inclusive of the bed charge. When we remember that the amount of metal melted in a foundry will range from 200 tons per year in a small foundry to 20,000 or 25,000 tons in the largest, and that good furnace coke costs about 20s. per ton, the urgent need for economy in melting is apparent.

Successful cupolas are too numerous for separate description. They include the old Ireland, the Woodward, the Krigar, the Voison, the Mackenzie, the Herbertz, the Colliau, and others well known in Britain, the United States, and the Continent. One of the best in present use is the Thwaites' "Rapid," Fig. 108. It embodies the air belt, the drop bottom, and the

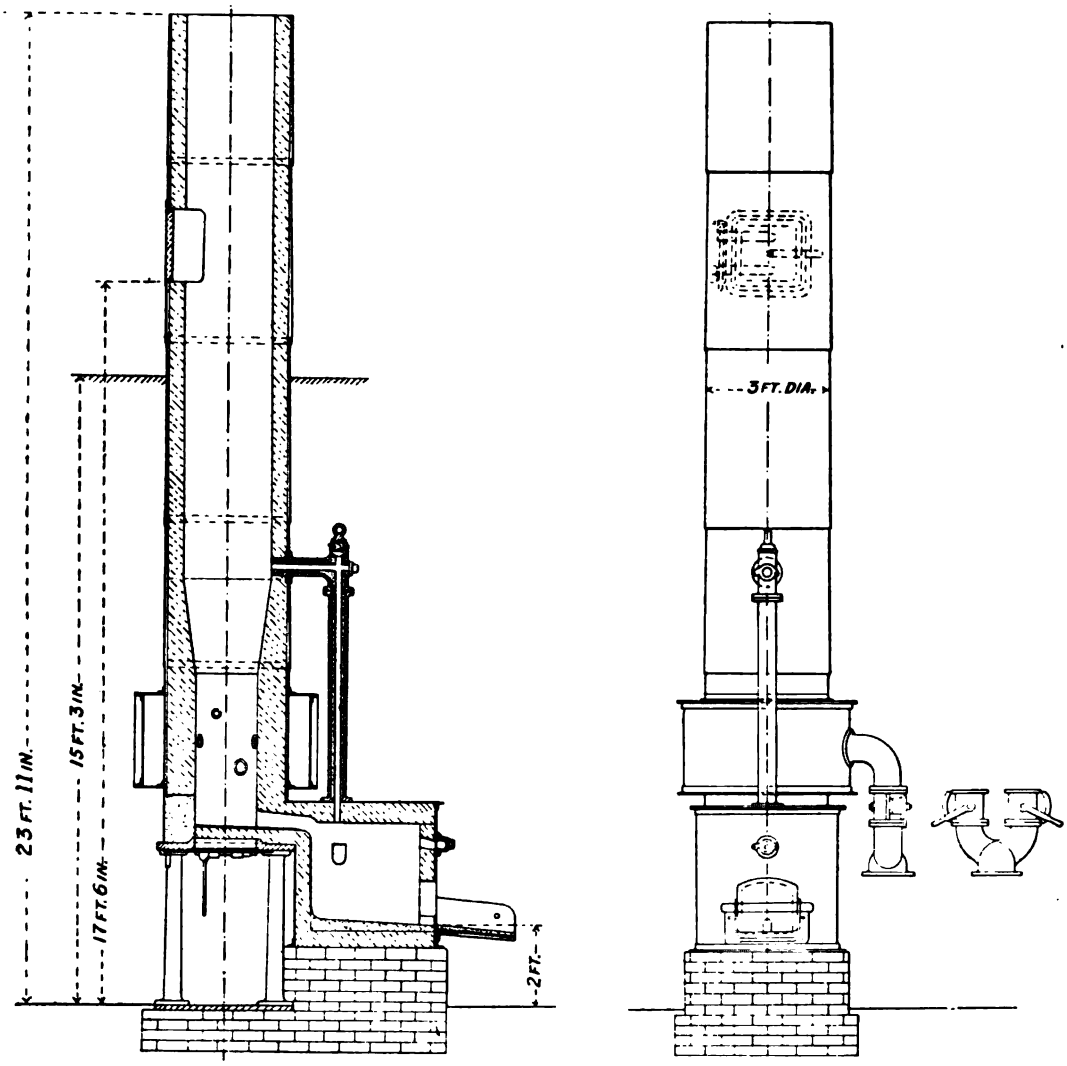
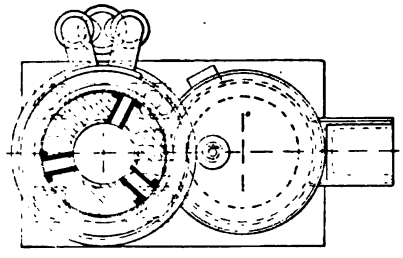


Fig. 108.—Thwaites' Cupola.



separate receiver, which receives heat from the cupola and keeps the metal hot. This cupola has shown very good records of about 2 cwt. of coke per ton of metal melted, inclusive of bed charge.

Cupolas used for melting the pig for Bessemer converters are larger than those employed in iron foundries. They measure from 8 feet to 10

feet in diameter inside. They have boshes, the blast is brought through a wind chest, the top is conical. The blast pressure is high, or from 2 lb. to 3 lb. per square inch.

Cup Shake.—A circular or ring shake, in timber.

Curb Ring.—A ring of teeth, external or internal, through which the slewing motion is imparted to a crane.

Current. — *See* **Alternating Currents, Dynamo.**

Curving of Patterns.—*See* **Camber, Castings—Curving of.**

Cushioning.—The admission of steam to a cylinder a short time before the termination of the piston stroke; it is regulated by the amount of lead of the valve. Spring devices applied to planing machines, to lessen the shock of reversal.

Cut.—A term in common use to signify the work of a cutting tool in a machine.

Cut-and-Cover.—*See* **Aqueduct.**

Cut-off.—The point at which the admission of steam into a cylinder is arrested. It is regulated by the amount of lap of the slide-valve.

Cut-off Valve.—A slide-valve working on the back of the main slide-valve, for the regulation of the expansive working of steam with a minimum amount of travel; sometimes called a grid-iron valve. It has its own eccentric distinct from that of the main valve.

Cutter Block.—The portion to which the cutters or knives in a wood-planing machine are attached. Also termed cutter-head, cutter-cylinder, planer-cylinder, adze-block. The type for planing up boards has the spindle forged solidly with a triangular, or a rectangular bar, having either screw holes, or vee-slots, by means of which the knives are held. Adjustment is effected by having slots in the knives, so that they may be pushed forward or backward as necessary. Either two, three, or four knives are used. The action of these is purely scraping, their high speed enabling effective work to be done. The short cutter-blocks for narrow work are mounted on a spindle; frequently a projection of the blocks stands out under the cutting edges, affording a bearing surface close to the edge. Cutters are frequently set at an angle, in order to give a shearing cut. Moulding cutters of various profiles may be held on these blocks. For the more intricate classes of work, rather complex heads are used, having means of adjusting for width, in grooving and matching. Specially narrow heads are made for grooving, the cutters being clamped by wedges forced in by setting screws.

Cutter Grinder.—*See* **Tool Grinders.**

Cutter-Pin Drill.—A counterbore. *See* **Drill.**

Cutting Angles.—*See* **Angles of Cutting Tools.**

Cutting-off Machines.—The old practice of cutting off bars or shafts for the lathe by the smith at the anvil has been largely superseded by the introduction of special cutting-off machines, which leave the work smooth and square at the ends. The essential mechanism is a rotating spindle, with chuck, and a cross slide carrying the tool. Fig. 109, Plate VIII., shows a good type, in which the spindle head is sunk into a bed, giving a rigid construction, the cross slide passing down the sloping face towards the centre. A stop at the right-hand end regulates the length of bar projecting from the chuck. An "increase-speed" device is fitted, employing taper cones (seen under the bed), the belt being gradually carried along so that the speed increases as the tool gets nearer the centre, where a higher speed of rotation can be permitted, and is desirable for rapid output. The tool is thin and deep, with concave sides to afford clearance. Some machines are provided with centring attachments, leaving the work ready for centres. Cutting-off is also done with the **Cold Saw, Hack Saws,** and **Hot Saws.**

Cutting Tools.—All tools which sever material by virtue of the wedge principle. They include the splitting as well as the paring or shaving-making tools, but not the scraping types. In strictness, cutting tools must have cutting angles of much less than 90°, and the cutting face must be presented at angles of less than 90° to the surface of the work being operated on, or to the tangent of the same.

The great groups of cutting tools are the chisels, planes, and chisel-like tools, as, for example, milling cutters, the turning tools,

the drilling and boring tools, and allied forms. The screw-cutting tools, a few of the saws, and files, some of the shears, and punches are on the border line. As each of these groups receive separate treatment in these volumes it is not necessary to repeat it here.

A point to note is that similar tools, varying only in cutting angle are brought to bear on all materials from softest to hardest; hardened steel, and chilled iron excepted. The differences made are those of cutting angle, breadth, and depth of cut, speed, and feed, and support or backing afforded. The wood-worker's chisel or plane easily removes chips and shavings, say from 1 inch to 2½ in. width, but those would be very wide cuts over metal, impossible without the backing up of a stiff shank held in a powerful machine.

The shape of a tool in plan, or in section is very important. The turner does not rough with the chisel, but with the gouge, because it penetrates and breaks up the material better. A jack plane with a good convexity to its iron roughs deeply before the trying plane finishes.

It is well known to the metal turner or planer that the type of tool which is the best for effecting the removal of material rapidly in quantity, namely, the common roughing tool, is not adapted for producing accurate work. The roughing tool turns or planes a series of grooves, the sectional shape of which is a counterpart of the curve of the tool point, and when a surface is wanted smooth and true it must be finished with a broad cutting tool, the edge of which is straight across. This is a familiar fact, but it is not so well understood or realised that the latter type of tool is displacing the former to a great extent in modern practice, fewer round nosed tools being used and more broad nosed tools with straight edges. This is largely due to the influence of the turret lathe. The "double edged" tool is a variant on the round nose, and has the advantage of finishing more smoothly, while penetrating better than the tool with a single straight edge.

In the double cutting tools represented by the drills and allied forms, we have examples of both narrow and broad edges, and of gouge and chisel-like shapes (the gouge in some of the wood boring bits). All drills for metal have the broad chisel-like edge, because no other is practicable for regrinding. The great difficulty in drills is the exact balancing of cutting action on each side of the centre, which relegates these tools to a class by themselves, hence the great value of the mechanical drill-grinding machines.

In the screw-cutting group the shapes of the cutting edges are rigidly fixed. It is difficult to impart any cutting angle, and to avoid injurious friction. Hence the importance attached to backing off, and to separating the guiding from the cutting functions.

Saws, files, shears, and punches are barely admissible into the group of cutting tools. Many are obviously scraping tools, and the variations in the shapes of these are not so wide as those which can be imparted to the chisel-like tools.

Cutting Wind.—An iron turner uses this term to denote the fact that work is revolving without being actually cut by the tool, as when there are gaps or breaks in the continuity of the circle. Also applied to planing, when the facings on work are tooled, by passing across from one side to another.

Cycle.—A complete circle of operations; applied to steam and gas engines, to the tooling of a piece of work on the automatic screw machine or capstan lathe, or to any series of operations carried through.

Cycle-Making Machinery.—This has much in common with plant for the manufacture of small arms, sewing machines, &c., comprising mainly capstan lathes, automatic screw machines, drilling machines, and milling machines; grinders occupying a limited place, for hardened work chiefly. The small size of the various components is favourable to form-turning and to form-milling, planing being hardly represented. The repetitive character of the work lends itself to the extensive use of jigs and special tools. One of the most interesting operations is hub turning, done with forming tools.

Presses for the sheet-metal portions are employed largely. Special drilling-machines for the spoke-holes in hubs are used. Rim-bending machines are also special to the work. Polishing is very extensively done, and sand-blasting plays a part in cleaning operations.

Cycloidal Gears.—*See* **Gears.**

Cylinder.—In mensuration, a cylinder is a solid figure produced by turning a rectangle round one of its sides, this side remaining fixed. To find the volume of a cylinder the area of the base is multiplied by the height. (The base of a cylinder is a *circle*.)

Volume = area of base × height.

If any two of these terms be known the third can be found:—

$$\text{Area of base} = \frac{\text{volume}}{\text{height}}.$$

$$\text{Height} = \frac{\text{volume}}{\text{area of base}}.$$

The area of the curved surface of a cylinder is got by multiplying the circumference of the base by the height of the solid. The reason for this rule is evident if we imagine a hollow cylinder unrolled and laid flat.

Surface area = circumference × height.

The areas of the ends (= twice area of base), must be added for the entire surface area.

Cylinder Boring Machines.—Cylinders are bored both in horizontal and vertical machines, noticed under those headings.

Cylinder Condensation.—The loss due to the difference in temperature of the steam and the metal in the cylinder, up to the point of cut-off, being proportional to the area of metal. Also due to the difference between the temperature of the steam at the point of cut-off and that of the exhaust steam. So that the loss is greater, the earlier the cut-off.

Cylinder Metal.—A tough, close grained, mottled mixture of cast iron which possesses a slippery surface when bored. Often it is made by the melter from grey pig, No. 4 Clyde, and selected strong scrap. Sometimes cold blast iron is used up to 50 per cent., instead of scrap.

Cylinder Oils.—*See* **Oils, Lubricants.**

Cylinders—Strength of.—The pressures on cylindrical vessels are either those tending to burst—internal stresses; or to cause collapse—external stresses. The two conditions are dissimilar.

Bursting Pressures.—Pressure in a cylindrical vessel is exerted equally in all directions. But it can be demonstrated that these lines of radial pressure may be resolved into forces acting in equal and opposite directions normal to the plane of the diameter. This is clear, because the forces must be equal and opposite, and act on equal areas. The sum of these vertical forces is equal to the total pressure operating on the diameter of the cylinder. The total pressure therefore equals the pressure per unit area, and length, multiplied by the diameter, or:—

Total pressure = pressure per unit area × length × diameter.

This has to be resisted by the thickness T of the material of which the cylinder is made, and which has a tensile strength t. It is not necessary to consider the total length of a cylinder subject to bursting pressure, but only a unit section, say 1 inch in length. So that the formula may stand:—

To obtain thickness—

$$T = \frac{d \times p}{2 \times t}.$$

To find the pressure that will rupture a cylinder of given thickness and strength—

$$p = \frac{T \times 2 \times t}{d}.$$

Where p = pressure in lb. per square inch.
d = internal diam. of cylinder in inches.
T = the thickness of metal.
t = the tensile strength.

In such a formula the ultimate strength may be taken, or a safe working strength. Or, as in riveted structures, the strength of the longitudinal riveted seams must be considered.

As a cylindrical vessel must have ends, the strength of the ends to resist bursting pressures must be taken into account. Actually, however, the question does not affect the strength of the cylindrical part, but that of the ends only. The pressure tending to rupture transversely to the axis is that exerted against both ends, which is equivalent to the internal area × the pressure per unit area, or:—

$$p = \frac{d^2 \pi}{4}$$

or, $p \times d^2 \times \cdot 7854$.

This has to be resisted by a ring or annulus of the material. The result is that a cylinder is subject to just half the stress in the longitudinal direction to that circumferentially.

This explains why double or treble riveting has to be adopted in the longitudinal seams of boilers, and single riveting in the circular seams. With regard to the influence of the ends in stiffening a boiler this is neglected in calculations. The strength of the ends is a different problem. *See* **Dished Ends, Flat Ends.**

Another thing is, that in considering the strength of cylinders we have assumed the case of those which are thin relatively to their diameters. In thick cylinders, though the mean stress remains unaffected, the inner rings are strained more severely than the outer. *See* **Thick Cylinders.** In ordinary work such as engine cylinders, and the shells of steam boilers the strength to resist fracture is directly proportional to thickness.

Collapsing Pressures.—Here the conditions are of an entirely different character from those first considered, and far more difficult to understand. Specifically the subject is one of vital and long-enduring interest in connection with the strength of boiler flues. *See* **Furnace Flues.** Fairbairn's historic experiments and formula were a battleground for more than a generation, until the Adamson seam showed others how to get round the difficulty and danger of long thin flues by dividing them into a number of short and practically independent lengths. For this reason it is hardly necessary to give much space to a problem that has lost much of its interest.

Sir William Fairbairn's formula was constructed for the collapsing pressure, and deduced from experiments conducted by hydraulic pressure within a cast-iron cylinder, Fig. 110. A is a strong cylinder of cast iron, within which the tubes were subjected to hydraulic collapsing pressure; B is the tube being experimented on; C is a pipe leading from the force-pump to the cylinder; D is a pipe for a pressure gauge, two such gauges being employed. The tube B is riveted to cast-iron ends, one of which has a pipe, E, passing through the top end of the cylinder, the other a rod, F, going through the bottom end. G is a safety valve for checking the readings of the pressure gauges.

At the outset this method could give no lessons as to what goes on in a steam boiler. The tubes experimented on were thin and short, whereas furnace tubes as used then were relatively thick and long.

Neither were the constants correctly deduced from those experiments. And so the historic formula for collapsing pressure was a stone of stumbling for many years:

$$P = 806,300 \times \frac{t^{2 \cdot 19}}{L \times D.}$$

Where P = the collapsing pressure in lb. per square inch,
t = tube thickness in inches,
L = tube length in feet,
D = external diameter of tube in inches.

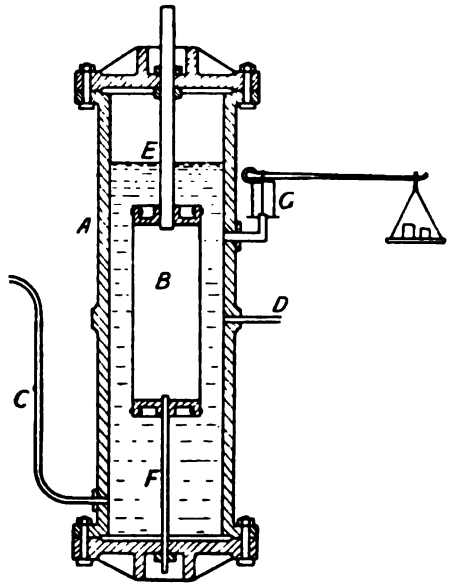


Fig. 110.—Fairbairn Experiments on Collapsing Strength.

Among those who have variously amended this formula are Longridge, Nystrom, Harrison, Booth, the Board of Trade, and Lloyds.

These have little interest now, because the shortening of flues by Adamson and other seams and rings, and stiffening by corrugations has got over the old difficulties in a satisfactory manner, as will be explained under **Furnace Flues.**

D

Dabbing on.—*See* **Welding.**

Dam.—A wall of masonry built up to withstand the pressure of water in reservoirs and barrages.

No single rule is possible for the design of dams, but local conditions must be taken into consideration. The broad rule may be stated thus:—The resultant of all the forces acting at any horizontal section must fall within the middle third of the thickness of the dam.

What is called the curve of pressure is a line drawn through the resultants of forces acting

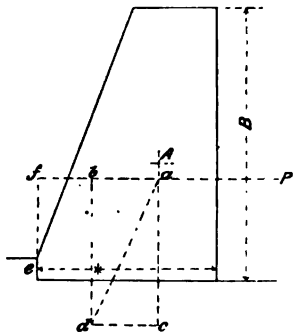


Fig. 111.—Stresses in Dam.

at different zones of depth. There are two such curves, one obtained from the reservoir empty, and involving stresses due only to the weight of the masonry; the other full. As a simple statement we may say that in dams of no great height it is sufficient to take the average pressure at the centre of gravity, and to consider this as concentrated at one point, the centre of pressure. Hence in calculating dimensions it is necessary first to assume an approximate profile, and test its stability by the resolution of forces, and repeating this twice or more if necessary.

Thus in Fig. 111 a vertical line is let fall from the centre of gravity, A, of the dam to intersect the horizontal line of pressure, P, which is taken at one-third of the height of the dam. From the point of intersection *a* the pressure is laid down to scale from *a* to *b*. The weight of the wall itself is laid down to scale perpendicularly from *a* to *c*. The parallelogram of forces is then completed, and the diagonal *a d* drawn, which scaled, gives the resulting thrust on the dam. The condition of stability is that it must pass well within the base. Or, as we stated just now, within the middle third of the thickness.

The tendency of the pressure P is to turn the dam over around the point *e*, at a radius of force *f e*, hence the reason why the resultant is kept a long way within *e*, so that the turning tendency is resisted by the weight of the masonry lying outside it.

In deep dams the thickness is divided into horizontal layers, each of which is made the subject of separate calculation, for weight of masonry, and horizontal thrust of water; and the stepped form which results is obliterated by drawing a curve through the inner angles of the successive steps. A batter of about 1 in 20 is usually given to the inner face.

Damper.—A plate by which the chimney draught is regulated in the furnaces of steam boilers, and melting furnaces. Generally it comprises a sliding plate in an iron frame, let into the masonry. It is horizontal in some cases, being drawn along by hand; or, as in boiler flues, it slides vertically, Fig. 112, A, and is counterbalanced. Often the revolving type, or butterfly damper B is preferred. The plate pivots in bearings in top and bottom of a cast frame built into the brick-work. The turning gear generally consists of bevel wheels. Dampers are frequently made wholly of cast iron, but alternatively the damper plate is a piece of sheet iron or steel. The damper for the chimney of a vertical boiler is shown at C.

Damping—Electric.—The checking of vibration, or the stopping of the oscillation of

an indicating pointer pivoted on an axis, and set in swinging motion by sudden variations of values indicated. A magnetic damping is effected in moving coil electrical indicating in-

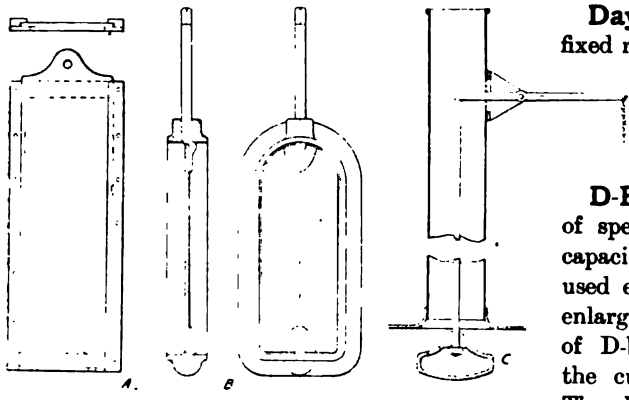


Fig. 112.—Forms of Dampers.

struments by almost surrounding the moving coil with an iron cylinder, which concentrates the magnetic field produced in the armature and brings the needle immediately to rest, when the value of its position is indicated at once.

Dam Stone.—A stone in front of the forehearth of a blast furnace backed up by a plate of iron, the dam plate, and through which the tap hole passes. On its upper edge there is a notch termed the cinder notch.

Daniell Battery.—A number of Daniell cells for use in series, or parallel connection.

Daniell Cell.—A primary electric battery. The positive element consists of a zinc rod contained in a porous pot, the pot being filled with a half-saturated solution of zinc sulphate. The outer vessel, having space for a copper cylinder, is filled with a saturated solution of copper sulphate, and forms the negative element. The cell maintains a fairly constant pressure of 1 volt, and is suitable for heavy intermittent service. *See* **Batteries, Primary.**

Danish Balance.—*See* **Balance.**

Dash-Pot.—A cylinder containing a dash piston, the action of which, controlled by a spring, closes the steam or exhaust valves sharply in engines of the Corliss type. The sharp concussion is deadened by dash springs of indiarubber, or of steel. An example occurs in **Compound Engine**, Figs. 40 and 41.

Datum Line.—A horizontal line from which vertical dimensions are taken either in civil or mechanical engineers' work.

Daubing.—Lining a foundry ladle with fireclay.

Day Work.—The system of working for a fixed rate of payment per hour, irrespective of the amount of work done per hour. Opposed to this is the system of piece work, and of the bonus or premium method of payment.

D-Bit.—A type of boring tool which is of special value for deep holes, due to its capacity for accurate guidance. It may be used either to start in the solid metal, or to enlarge a hole. Fig. 113 gives two examples of D-bits. A is forged solid with its shank, the cutting lip *a* standing up at an angle. The shank is cranked so that it cannot touch the sides of the hole. The tool end only is made of cast steel, the shank being of mild steel welded on, to save the more costly material. B has the cutter detachable, one of the advantages of which lies in ready replacement in case of breakage, without the need of re-forging. The slots in the cutter permit of endlong

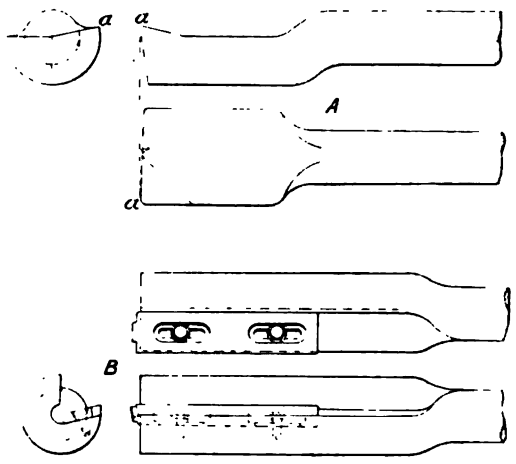


Fig. 113.—D-Bits.

adjustment to compensate for the shortening caused by grinding.

Ample lubrication is necessary to enable these tools to penetrate deeply, an oil pipe being carried along the body nearly to the nose, so

that the cuttings are washed out of the hole, and the tool and work kept cool. D-bits are generally used in the lathe, the work being revolved by the chuck or face-plate, and if necessary supported by a cone-plate, or a steady, the drill being fed up by the poppet. It can be made and used in small and large diameters, and up to several feet in length. It possesses the valuable property of boring a very true hole of any length, if it is started truly in a hole first entered by a boring tool held in the slide rest. It can be used face upwards or downwards, but requires an abundant flow of soapy water or oil, and has to be withdrawn at intervals.

Dead.—A term of rather extensive application. Dead metal is metal either insufficiently melted in the first place, or metal which has been allowed to become too cool for the purpose for which it is required. But dead melting is complete fusion. A surface is dead level when it is as level as possible. An accurate piece of machining is said to be dead true, or dead square. A dead blow is one devoid of elasticity, which would tend to cause a rebound. A dead head denotes head metal, or the mass of metal in a pouring basin, or in a feeder head. A dead axle is an axle which is not a driver. Dead water is the sluggish water that lies below the heating surface in a steam boiler. Other definitions are treated below with slight amplifications.

Dead-Beat Ammeter.—An ampère-meter having a magnetic damping device, or an air or oil dash-pot, to check the oscillations of its pointer, and so bring it quickly to rest when its indication is suddenly altered.

Dead Centre Lathe.—One in which the centre of the fast headstock does not revolve, but in which the work is rotated on fixed centres. All the early lathes were of this type, and all the native lathes of the East are to-day. The early millwrights used them. The running mandrel lathe seems to date from a period a little prior to 1568. At present the representatives of this type are found in the axle-turning lathes, in the watchmaker's lathes, and in high-class grinding machines, which combine provision for grinding on dead centres, and on a running mandrel. The dead centre lathe is only of value when extreme accuracy is required, and has no place in ordinary engineers' work; the circular grinding machine, and the **Axle Lathe** excepted. In the latter the choice is one of convenience only, because the axle is driven by the central headstock.

Dead Centres, or **Dead Points.**—Signifies that the axis of a piston rod, crank shaft, and crank pin are all in one plane. In such a position an engine cannot be started by the admission of steam alone, but help is necessary to get it over the centres. In a single engine this is done by pulling, or barring the fly-wheel round. In double engines the cranks are set at angles of 90°, so that if one should be on dead centres, the other pulls it round. Turning on dead centres is work done in a **Dead Centre Lathe.** Sometimes turning done between the conical centres of the running mandrel and of the loose poppet is termed dead centre turning, but that is not correct. It is work *between* centres.

Dead Earth.—When two insulated conductors come in contact with the earth, through a negligible resistance, a current will flow through the earth in proportion to the resistance of the conductors, and the contact, and the E.M.F. of the source of current. As this resistance will usually be of less value than that of the prescribed path, the current having that path and the earth path in parallel, the greater proportion of it will be diverted and take the earth as a short circuit, and so leak and be lost. Hence the importance of keeping at least one of the conductors thoroughly insulated.

Dead Eye.—A solid bearing for a shaft, to distinguish it from a bearing with a removable cap. It may or may not be bushed with gun-metal. Generally it has the form of a boss, with a foot for bolts.

Dead Load.—A load which does not change either in nature or intensity. It is either wholly tensile, or compressive; it is steady and constant in character. It is the least dangerous form of load, imposing less stress, and requiring a lower factor of safety than live or variable loads do.

Dead Load Safety Valve, or **Dead Weight Safety Valve.**—A type which owes its value to the fact that the exact loading is given by weights, the number of which

may be regulated, and which show at a glance the maximum boiler pressure. The construction of a good example is shown in Fig. 114, in which a low-water alarm is fitted in conjunction with the steam safety valve. The valve comprises an inverted cylinder on the lower end of a long stem, the lower edge of the cylinder forming an annular facing of conical section fitting on the seating below. Risk of sticking of the stem is prevented by making it

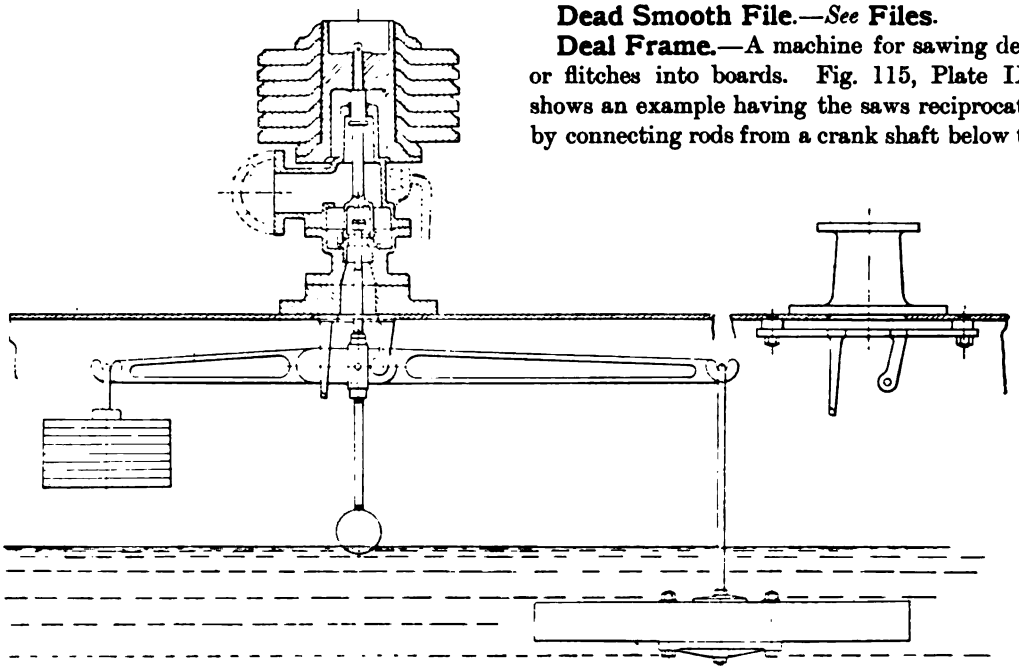


Fig. 114.—Dead Load Safety Valve. (Alex. Turnbull & Co., Ltd.)

of good length, and a free fit in its bush above. The valve is prevented from lateral displacement by wings projecting upwards from the seating. There is a main weight resting on the upper end of the stem; and around, and on this the ring weights are placed. The loaded valve can be lifted for testing by a cam and handle. The low-water alarm is distinct from this in its operation, though connected therewith. A lever pivoted in a lug carries the float at one end, and a balance weight at the other. A loaded vertical rod at the centre remains always under the centre of the safety valve. When the water gets low and the float sinks, the vertical rod pushes up the safety valve, so that steam if present escapes; or if steam is not got up, it cannot be generated at all, the valve remaining open. This type is sometimes known as a Cowburn Valve.

Dead Parallel File.—*See* **Files.**

Dead Plate.—The plate just within the furnace doors of a horizontal steam boiler, on which the fuel is first thrown, to be partly coked before being pushed over the bars.

Dead Points.—*See* **Dead Centres.**

Dead Smooth File.—*See* **Files.**

Deal Frame.—A machine for sawing deals or flitches into boards. Fig. 115, Plate IX., shows an example having the saws reciprocated by connecting rods from a crank shaft below the floor, the level of which is at the lugs seen on the side of the framing. The timber is fed between rollers to the saws, at the top part of the frame, a variable rate of feed being imparted by the disc friction gear at the bottom right-hand corner, connecting to gears driving the vertical feed rollers. The machine shown takes two deals at once.

Deals.—Converted pine timber, sawn to dimensions of over 9 in. by 3 in. 11 in. by 3 in. are usual dimensions for deals, but many are wider. Length is variable.

Decarburisation.—The removal of carbon from iron in the Bessemer converter, the open-

hearth furnaces, the puddling furnaces, and in the manufacture of malleable cast iron.

Decimal.—A decimal is a number expressed in a decimal notation, that is, on a scale of tens. Just as in the number 111, each figure *increases* tenfold (100 + 10 + 1) in progressing to the left, so by affixing a decimal point, ·111, each figure *decreases* tenfold towards the right ($\frac{1}{10} + \frac{1}{100} + \frac{1}{1000}$). The great advantage of this system, especially in engineering, is seen in the facility with which fractions of weights and measures are added, subtracted, multiplied, and divided. Its great disadvantage is that many fractions cannot be expressed exactly as decimals. If, for example, an attempt be made to represent $\frac{4}{9}$ or $\frac{5}{11}$ in a decimal form it is found that the same figures recur in the quotient *ad infinitum*, $\frac{4}{9}$ = ·44444, &c., $\frac{5}{11}$ = ·454545, &c. *See* **Decimal Fractions** and **Metric System.**

Decimal Equivalents.—It is more than ever necessary to have dimensions in decimals corresponding with vulgar fractions. To avoid the trouble of calculation, these are given in tables, one of which is annexed.

TABLE OF DECIMAL EQUIVALENTS OF 8THS, 16THS, 32NDS, AND 64THS OF AN INCH.

8ths.	16ths.	32nds.	
$\frac{1}{8}$ = ·125	$\frac{1}{16}$ = ·0625	$\frac{1}{32}$ = ·03125	$\frac{17}{32}$ = ·53125
$\frac{2}{8}$ = ·250	$\frac{3}{16}$ = ·1875	$\frac{3}{32}$ = ·09375	$\frac{18}{32}$ = ·59375
$\frac{3}{8}$ = ·375	$\frac{5}{16}$ = ·3125	$\frac{5}{32}$ = ·15625	$\frac{21}{32}$ = ·65625
$\frac{4}{8}$ = ·500	$\frac{7}{16}$ = ·4375	$\frac{7}{32}$ = ·21875	$\frac{23}{32}$ = ·71875
$\frac{5}{8}$ = ·625	$\frac{9}{16}$ = ·5625	$\frac{9}{32}$ = ·28125	$\frac{25}{32}$ = ·78125
$\frac{6}{8}$ = ·750	$\frac{11}{16}$ = ·6875	$\frac{11}{32}$ = ·34375	$\frac{27}{32}$ = ·84375
$\frac{7}{8}$ = ·875	$\frac{13}{16}$ = ·8125	$\frac{13}{32}$ = ·40625	$\frac{29}{32}$ = ·90625
	$\frac{15}{16}$ = ·9375	$\frac{15}{32}$ = ·46875	$\frac{31}{32}$ = ·96875

64ths.			
$\frac{1}{64}$ = ·015625	$\frac{17}{64}$ = ·265625	$\frac{33}{64}$ = ·515625	$\frac{49}{64}$ = ·765625
$\frac{3}{64}$ = ·046875	$\frac{19}{64}$ = ·296875	$\frac{35}{64}$ = ·546875	$\frac{51}{64}$ = ·796875
$\frac{5}{64}$ = ·078175	$\frac{21}{64}$ = ·328125	$\frac{37}{64}$ = ·578125	$\frac{53}{64}$ = ·828125
$\frac{7}{64}$ = ·109375	$\frac{23}{64}$ = ·359375	$\frac{39}{64}$ = ·609375	$\frac{55}{64}$ = ·859375
$\frac{9}{64}$ = ·140625	$\frac{25}{64}$ = ·390625	$\frac{41}{64}$ = ·640625	$\frac{57}{64}$ = ·890625
$\frac{11}{64}$ = ·171875	$\frac{27}{64}$ = ·421875	$\frac{43}{64}$ = ·671875	$\frac{59}{64}$ = ·921875
$\frac{13}{64}$ = ·203125	$\frac{29}{64}$ = ·453125	$\frac{45}{64}$ = ·703125	$\frac{61}{64}$ = ·953125
$\frac{15}{64}$ = ·234375	$\frac{31}{64}$ = ·484375	$\frac{47}{64}$ = ·734375	$\frac{63}{64}$ = ·984375

TABLE OF EQUIVALENTS OF MILLIMETRES IN DECIMALS OF INCHES.

mm.	in.	mm.	in.	mm.	in.
$\frac{1}{10}$ =	·00394	8 =	·31496	18 =	·70866
$\frac{1}{5}$ =	·00787	9 =	·35433	19 =	·74803
$\frac{1}{2}$ =	·01969	10 =	·39370	20 =	·78740
1 =	·03937	11 =	·43307	21 =	·82677
2 =	·07874	12 =	·47244	22 =	·86614
3 =	·11811	13 =	·51181	23 =	·90551
4 =	·15748	14 =	·55118	24 =	·94488
5 =	·19685	15 =	·59055	25 =	·98425
6 =	·23622	16 =	·62992	26 =	1·02362
7 =	·27559	17 =	·66929		

Decimal Fractions. — Since a decimal fraction has for its denominator 10, or some power of 10, it may be represented as a vulgar fraction by taking for the numerator the figures in the decimal, and for the denominator as many noughts as there are figures in the decimal and prefixing 1. Then cancel where possible. Thus ·9 = $\frac{9}{10}$, ·014 = $\frac{14}{1000}$ or $\frac{7}{500}$, 1·21 = $1\frac{21}{100}$.

Addition and subtraction of decimal fractions are performed as with ordinary whole numbers, the quantities to be added or subtracted having first been arranged so that the decimal points come under one another. Thus add 42·173 + ·001 + 61 + 1·97, and subtract ·197 from 827·51.

42·173	
·001	827·510
61·000	·197
1·970	
105·144	827·313

Ciphers are put in as above to complete a line of figures, but this may be done mentally.

In multiplication of decimals, ignore the decimal points and proceed as with whole numbers. Then in the result, place the decimal point as many places from the right as there are in the multiplier and multiplicand. By "decimal places" is meant the number of figures on the right of the decimal point.

	·241 × ·13
	·13
34·213 × ·04	723
·04	241
1·36852	·03133

When, as in the second example given, there are not the required number of decimal places in the answer, as many ciphers are added as are necessary.

Of the methods of division of decimals the simplest is to make the divisor a whole number, and to put the decimal point in the quotient immediately it is reached in the dividend. Therefore ·643214 ÷ ·11 becomes 64·3214 ÷ 11, the dot being shifted two places in divisor and dividend. And ·0001 ÷ ·0015 = 1 ÷ 15. Then:—

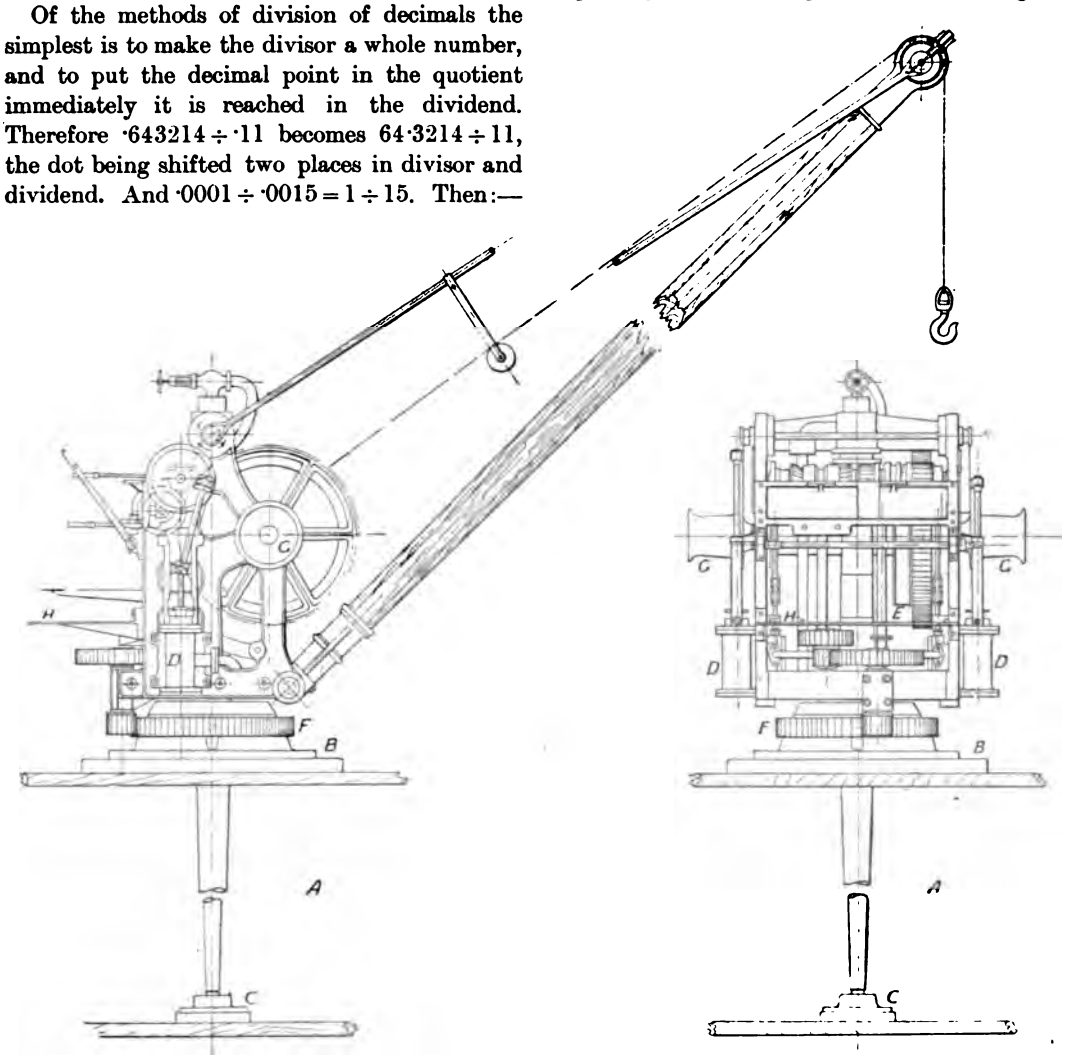


Fig. 116.—Deck Crane.

$$
\begin{array}{r|l}
11 & 64{\cdot}3214 \\
\hline
 & 5{\cdot}8474
\end{array}
$$

$$
\begin{array}{l}
15)1{\cdot}00(\cdot06 \\
\quad 90 \\
\quad \overline{} \\
\quad 100 \\
\quad 90 \\
\quad \overline{} \\
\quad 10
\end{array}
$$

In the last example the figure 6 repeats to infinity, and no quotient exactly correct can ever be obtained. In such cases the digit or set of digits recurring is marked thus—·06, 3·10$\dot{9}$5, ·5$\dot{4}\dot{2}$, and the decimal is called a recurring, repeating, or circulating decimal. Where great exactness is required, addition, subtraction, multiplication, and division should be performed by first bringing the recurring decimal to a vulgar fraction and then performing these processes, and in the last two rules at least this method is in the majority of cases advisable. Addition and subtraction may however be more quickly performed by carrying out the recurring figures to several places. Thus 3·10$\dot{9}$5 − ·1$\dot{4}$ =

3·10950950 – ·141414. The result, though never quite exact, would be quite sufficiently so for engineering purposes.

Recurring decimals are converted to vulgar fractions according to the following rules:—In pure circulating decimals (those in which all the figures after the decimal point repeat), write down all the figures which repeat for the numerator, and for the denominator set down as many 9's as there are figures which circulate. Thus $\cdot\dot{7}\dot{6} = \frac{76}{99}$. In mixed circulating decimals (in which non-recurring figures follow the point), for the numerator, subtract the non-recurring figures from the figures taken to the end of the first period, and for the denominator, as many 9's as there are recurring figures and as many noughts as there are non-recurring figures. Thus $\cdot 54\dot{3} = \frac{543 - 54}{900} = \frac{489}{900}$.

Deck Crane.—A class of fixed crane usually fitted on board ship, driven either by hand power, steam, or electricity. The distinctive feature is the compactness of design, which is necessary in order to economise space as much as possible. Hoisting and slewing motions are as a rule only fitted; the jib is arranged to be readily lowered to the deck, or to be removable bodily for storage. The centre post or column around which the crane revolves usually extends below the main bedplate and has a seating on a lower deck.

Steam deck cranes receive their steam supply either from the main boilers of the vessel, or else from a separate donkey boiler; in the former case it is usual to fit a reducing valve on the boiler in order to deliver steam at about 60 to 70 lb. per square inch at the crane. The supply pipe connects to a flange on the crane post below the deck, the post is bored for the passage of steam, and has a swivel gland fitted at its upper extremity from whence piping connects to the engines. The exhaust steam is led to an annular casing fitted to the main bedplate from which it may discharge direct to the atmosphere, or, by means of pipe connections overboard.

In Fig. 116, A is the space between decks, through which the post passes down from its base plate B above to the footstep C below. The side frames are connected by cross stretchers, and the whole swivels bodily round the post. Two vertical engines D D drive disc cranks on the ends of the main engine shaft, the gears of which drive the lifting and lowering motions (with a band brake E as an alternative for the latter). Also the slewing through the friction cones, with double gear reduction to the curb ring F. Warping cones G G are fitted on the drum shaft. The various operating levers are within reach of the man on the platform H behind the crane.

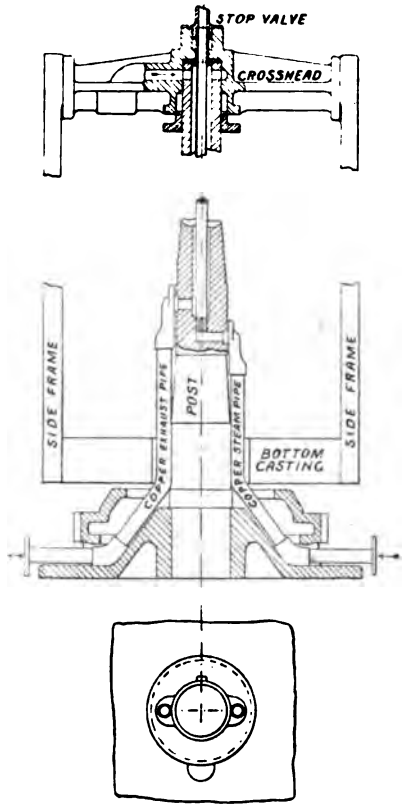


Fig. 117.—Pipe Arrangements for Deck Crane.

A special feature of this crane is shown in detail in Fig. 117, viz., the fitting of the steam and exhaust pipes in a very unique and compact manner, one great advantage gained being that all the steam joints are above the deck and quite easy to get at. It will be observed that a centre casting is fitted around the post, and encircled in turn by a bottom casting; two holes are provided in the centre casting for

the passage of the steam and exhaust pipes. The rest of the connections will be readily followed from the illustration. The crane is designed and manufactured by Messrs Robert Roger & Co., Ltd., Stockton-on-Tees.

Deck Winch.—*See* **Winches.**

Decomposition of Water.—*See* **Water.**

Deep Well Pump. — *See* **Bore Hole Pump.**

Deflagration. — Denotes the rapid combustion produced when such substances as potassium nitrate (KNO_3) or chlorate ($KClO_3$) are thrown on red-hot charcoal.

Deflection.—The bending of a beam under a load. The deflection must never exceed that corresponding with the elasticity of the material; that is, the beam must return to its original state on the removal of the load, for if otherwise, permanent set will follow. The amount of deflection is measured in testing machines for specimen bars, but in large structures by a straining line of fine wire, or by a theodolite. Specifications give the maximum amounts of deflection permissible for specimen bars, and for complete structures, comprising girders subjected to maximum loading.

Degree.—A degree is the 360th part of the circumference of any circle. The magnitude of an angle is measured by the number of degrees contained in the arc subtended by that angle. Each degree contains 60 minutes, and each minute 60 seconds; 14°, 25′, 34″ denotes 14 degrees, 25 minutes, 34 seconds.

A degree is also the unit of measure in thermometers, but varies according to the scale. For this, see **Thermometer.**

Deliquescence. — *See* **Chemistry** (Vol. III., p. 221).

Delivery.—Signifies the withdrawal of a pattern from the mould; synonymous with lift, as a good, or bad delivery, or lift. Also the ejection of liquids from the discharge of pumps through valves and pipes, hence termed delivery valves and pipes. The delivery box of a pump is the chamber which receives the liquid from the suction, and from which it is discharged.

Delta Metal.—The term is applied to a range of alloys varying in composition to suit various applications in cast and forged work; and in the form of sheets, tubes, wire, &c.; being substituted for cast iron, brass, bronze, wrought iron, and steel in different cases. It is as a very tough bronze, and as a rival to those alloys that contain a very small quantity of iron and manganese bronze, that it is chiefly used. The Delta Metal Company denote the different qualities by Nos. I., II., III., IV., &c., each of which possesses certain characteristics of special value.

No. I. Delta is a tough bronze, which is suitable for casting, forging, rolling, or stamping. When cast it has a tensile strength of about 40 tons per square inch, an elongation of about 20 per cent. on 2 inches, with a reduction of area of about 20 per cent. The forged alloy has a tensile strength of about 43 tons, and extruded Delta metal, No. I., 48 tons per sq. in. A valuable feature is its resistance to corrosion, which renders it of value in marine engine parts, and mining, and hydraulic plant; as pump rods, plungers, spindles, valves, &c. No. II. Delta is an alloy chiefly used for ornamental work, either cast or stamped. No. III. is suitable for solid drawn tubes. No. IV. is the one most commonly used for general purposes. Its tensile breaking strength varies, being from 23 to 25 per cent. cast, and about 35 forged, with 30 per cent. and upwards elongation. It resists corrosion excellently.

Delta is melted in crucibles, or in air furnaces. Moulds must be made in free open sand, with coal dust, and well dried. The cores must not be coated with plumbago, but with lamp black mixed with water, with a pinch of potato flour added. Venting must be ample; the gates and risers should be rather larger than for brass. The shrinkage is $\frac{3}{16}$ths in. per foot. The molten metal must not be overheated. Its surface is covered with charcoal, or coke dust, and when removed from the furnace the metal is stirred with an iron rod, and left standing for a minute or two, and then skimmed. Borax is added, the skimming repeated, and the pouring done. Delta is forged at a dull cherry red. It must not be heated rapidly, nor overheated, nor worked at a black heat, nor dipped in water. It cannot be tempered, but its hardness and elasticity can be increased by cold hammering.

Demurrage.—When a vessel is chartered by a firm for its service, a certain number of

days (lay days) is usually named as to be occupied by loading or unloading. If this period is exceeded, the firm or person chartering the vessel is liable to extra charge as demurrage. If no agreement is made as to time, the usual custom of the port is taken to settle the time to be allowed.

Density.—By the mass of a body is understood the quantity of matter contained in that body. But if a certain volume, say a cubic foot, of different substances be taken, the quantity of matter contained in each will vary. This is obvious in the case, for example, of equal volumes of cork, elm, and ebony. Ebony has greater density than elm, and elm is denser than cork. This is due to the greater crowding together of the particles composing the body. Density, then, means the degree of concentration of matter in the body, and is defined as the mass per unit volume.

Deoxidisation.—The elimination of oxygen from oxides of the metals in various metallurgical processes; in the blast furnace, in calcination, puddling, &c.

Dephosphorisation. — The removal of phosphorus from the metal in the Bessemer converter, in the open-hearth furnaces, and in the puddling furnaces, the methods of which are described in connection with those processes. The basic process is termed a dephosphorising process because the element is eliminated in this, while it is not in the acid process.

Deposit.—Signifies specifically the accumulations of sediment and incrustation to which steam boilers and water supply pipes are liable. *See* **Boiler Explosions, Boiler Scale, Feed Waters, Incrustation.**

Depreciation.—The practice of writing off annually a certain percentage of the value of factory buildings, machinery, and plant. This may take the form of a fixed proportion of original outlay, or a percentage of a value that diminishes each year. The same end may be met by providing a sinking fund, or a reserve out of revenue, and only applying income for purposes of dividend after this charge has been met. There must always be much uncertainty in regard to the amount to be allowed for depreciation. When machines are new and of modern types it seems unnecessary to begin to write anything off their value almost as soon as they are laid down. But experience of the past demonstrates the fact that much machinery becomes obsolete while still showing little sign of wear. A new invention or process comes to the front, and must be adopted, or ground lost. How the high speed steels introduced in 1900 are changing lathe design is a matter of present observation. Electric driving is having the same result in another way. The growth of the practice of milling and of gear cutting are modifying the designs of the machines. The case of blast furnace practice, the plant for steel-rolling mills, and other industries might be cited.

An average rate of depreciation on machine tools and engineers' plant is from 7½ to 10 per cent. The 5 per cent. of years ago is not enough in these times. If it should happen, as it often does, that the allowance made is not warranted by subsequent experience, then the assets of the firm are of more value than the estimate would show. Actually many machines, though nominally depreciated to zero, have a considerable value, not only to the firm, but also if sold. They remain for years after they have become normally worthless, and earn as much money for the firm as when they were new.

Depth Gauge.—A tool used by wood and metal workers for measuring the depth of holes, slots, key-grooves, &c. It is particularly useful for die-sinkers. Sometimes a rule only is employed, resting its end on the bottom of the recess and reading the divisions off at the top, but no record of the size is thus obtained, and very exact gauging is not easy. Gauges are therefore made for this work, having sliding parts, which remain in place after setting. A few typical designs are shown in Fig. 118.

A is a rule fitted with a sliding wire indicator, the tail of which points to the graduations on the face; the small size of the wire permits of its insertion in very narrow holes. In an allied type, a flat slide fits in the rule, and reads to inches on one side, and metric divisions on the other. A vernier is also placed on the slide. B comprises a narrow rule having an adjustable stock clamped by a bolt, the head of which is grooved to embrace the rule, and pulled down on it by a nut at the back. A round rod is

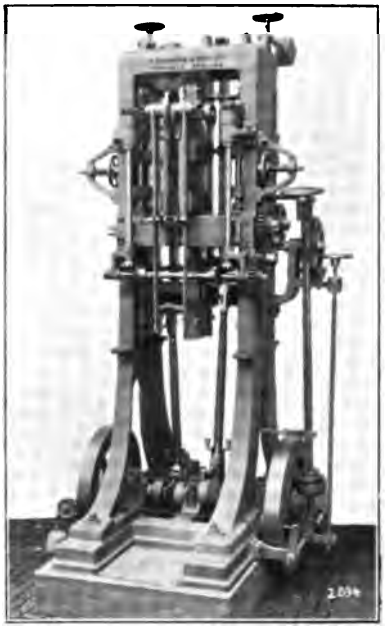


Fig. 115.—Double Deal Frame.
(Thos. Robinson & Son, Ltd.)

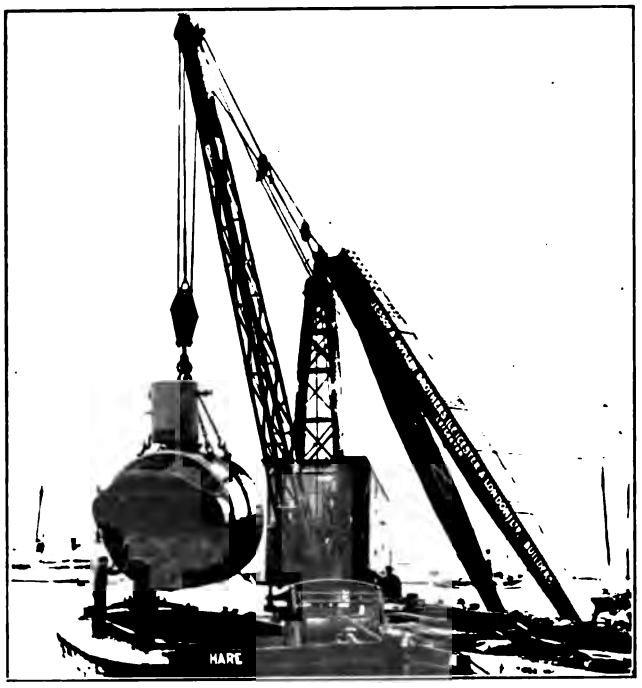


Fig. 119.—30-Ton Electric Derrick Crane.
(Jessop & Appleby Bros., Ltd.)

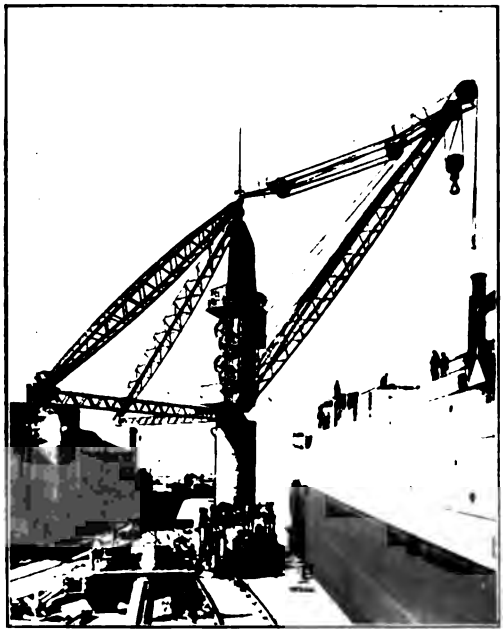


Fig. 120.—100-Ton Electric Derrick Crane at Scott's Dock, Greenock.
(George Russell & Co., Ltd.)



Fig. 123.—Front Feed Refuse Destructor.
(Meldrum Bros., Ltd.)

To face page 116.

fitted alternatively at C, and is also gripped by a bolt head. Graduations are sometimes located on the face of the stock, to be read in conjunction with inch or half-inch lines on the rod. Provision for using both a rule and a wire is included in type D, the bolt pressing on the bevelled edge of the rule, as at *a*, or on top of the wire, as at *b*. Either the slot at the end or at the centre may be used, according to which is more convenient. The slot at *c* has a slight taper, of one degree, for use when cutting dies, or patterns.

A scribing block may be used as a depth gauge by passing the rod down through a hole or slit in the base, and resting the latter on the work face. The term Depthing Square is often applied to the type shown in B. *See also* **Micrometer Gauge.**

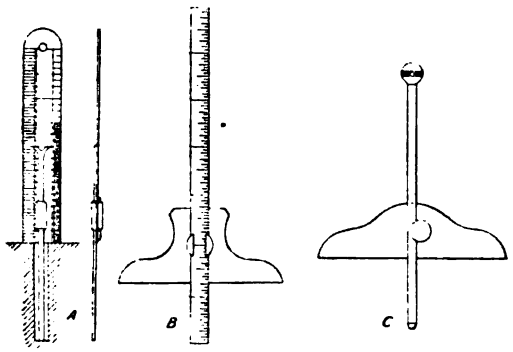


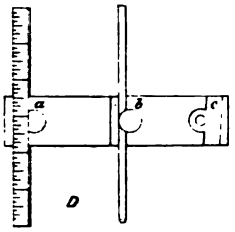
Fig. 118.—Depth Gauges.

Derrick.—A boom of timber stepped into a circular block or forging at the foot of a mast, and held at its outer extremity by stays secured to the head of the mast. It is used in combination with a steam winch on board ship for unloading from hatchway to quay, or to boat alongside; guy ropes are attached at the head of the boom to provide means for swinging it sideways.

Derrick Crane.—A form of crane which consists essentially of a vertical mast pivoted at the top and bottom, fitted with a jib, hinged at its lower end, and having appliances for varying the radius. The bottom pivot of the mast usually rests in a toe-plate, whilst the upper pivot is held by forgings and back stays; these latter are placed at right angles in plan, and the jib can sweep round about 260 degrees when slewing. These cranes are used largely in Great Britain and America for quarries and general contractor's work; they are made both as fixed and portable machines; the motive power may be either hand, steam, or electricity. Figs. 119, 120, Plate IX., show modern examples of steel-built derrick cranes.

A distinguishing feature of the derrick crane is the **Derrick Gear**, whereby the load is maintained in a horizontal line whilst the radius of the jib is being varied.

The portable or travelling derrick cranes are mounted on three trucks or trolleys, connected to each other with horizontals. The main truck carrying the mast has travelling gear fitted, and a shaft is carried across to the opposite truck to drive that simultaneously. The two guys or legs are attached to the subsidiary trucks, which are loaded with pig or ballast.



Derrick Gear.—The gear which varies the radius of a crane jib. An ordinary crane has the derrick gear separate from the hoisting gear, but a **Derrick Crane** has the two gears coupled together; by this latter arrangement the hoisting chain is payed out when the jib is derricked in, and *vice versa;* the nett result is that the load is kept at a constant level, which is not the case when the gears are separate. The mere coupling of the gears does not always ensure the load moving in a horizontal line, although in some derricks it is sufficiently approximate. The original inventor, Henderson (1845), made the derrick barrel itself in taper or fusee form, and so arranged it that when the jib was at its greatest radius the chain was winding on the smallest diameter; as the jib was derricked inwards the chain wound gradually on the larger diameters, and consequently payed out a decreasing quantity

of hoisting chain. This compensated for the inconstant ratio which existed between the movement of the jib and the necessary paying out of the hoisting chain to keep the load horizontal. When a derrick crane is required to simply hoist or lower a load, the derrick gear is disconnected from the hoisting gear by means of a clutch, the jib being prevented from falling by a ratchet and pawl fitted to the derrick barrel.

Design, Designing.—Motors or machines are rarely designed *ab initio*. Original ideas are essential to the making of a capable designer, but they must generally be held in check by an extensive experience in practical engineering. It is true to say that with very few exceptions successful mechanisms have been evolved through much labour and failure. The locomotive, and other engines, all the great groups of machine tools, cranes, electro-motors, &c., are cases in point. Economy of construction and in operation is just as essential in designing as mechanical efficiency. Hence the designer requires to be in touch with the shops, or to be subject to correction therefrom.

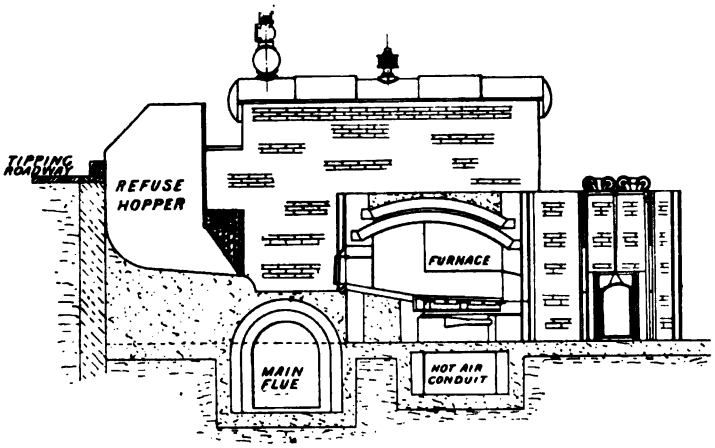


Fig. 121.—Meldrum Destructor. Back Feed Type. (Meldrum Bros., Ltd.)

Destructor.—A furnace designed for the burning of town's refuse. With the growth of cities the disposal of the accumulations of garbage becomes a pressing problem. It has been estimated that from 15 to 20 cwt. of refuse are produced daily per thousand of the population. In many cities this is allowed to accumulate in vast tips, at great expense for haulage, and a menace to public health. This refuse, though not of high calorific value, can yet be burned with a saving of expense to ratepayers by comparison with the tip method of disposal. The heat produced can be utilised for lighting or power, though the value of this obviously depends on the calorific value of the refuse, which ranges from about one-fifth to one-fifteenth that of coal.

There are several types of destructors now in use. Most of them comprise a series of independent units or cells arranged in line, and often also back to back. The first erected in Great Britain were designed by Messrs Manlove, Alliott, & Co., Ltd., in 1876. The principle was that of charging the refuse to the cells at the back, and drawing out the clinker at the front, the principle upon which other destructors have been built, with improvements. Destructors differ in respect of the charging arrangements and other details, and in being worked at low and high temperatures. The following remarks relate to some of their leading features only.

Fryer Destructor. — This, when fitted with Boulnois, Wood, and Brodie's combination, is comprised of cells, with a boiler (Babcock & Wilcox usually) set between two cells, which receives the gases from both of them. The charging apparatus comprises tanks travelling on rails under the tipping floor, whence they each receive sufficient refuse for a single charge. Being on rails they are brought over any cell, and the contents are discharged through a hinged bottom on to the drying hearth, after which the refuse is raked forward over the fire-grate, which has rocking fire-bars, and is usually provided with artificial draught.

The Warner Destructor.—In the charging apparatus of this type, there is a hopper set behind the drying hearth, having a hinged door

at its base, which, being opened by a lever operated from the tipping floor, drops the refuse on the drying hearth, from whence it is raked forward. The rocking-bars in this have been generally superseded by fixed ones, inclined at a steep angle. Dampers are fitted for the isolation of cells, and fan draught is used.

The Meldrum.—The destructor by Meldrum Bros., Ltd., has been designed and developed on original lines. It was the first to produce steam at a pressure of 200 lb. per square inch from destructor gases (at Darwen in 1899) used for electric lighting, and traction. It employs a regenerator in conjunction with one large cell having a continuous grate, but with divided ashpits, so that the whole of the grate, or particular sections only of the same can be worked. Forced draught is supplied to each ashpit by means of steam jet blowers, and each is under separate control.

There is a continuous chamber above the grate instead of isolated cells. The gases in their passage from the grate pass over the bridge into the combustion chamber, and thence through and around the boiler. After leaving the boiler they pass through an uptake and down through a regenerator, consisting of cast-iron pipes around which cool air circulates. The air thus heated is then drawn from the regenerator and delivered to the blowers under the grate at a temperature of about 350° Fahr. One result is that no drying hearth is necessary. Fig. 121 is a section through one regenerative "back feed" type, and Fig. 122 one of "top feed" type. There is also a "front feed" type built, shown by the photo, Fig. 123, Plate IX.

The Horsfall Destructor.—This is a high temperature type, and was the first made. It has an inclined drying hearth, Fig. 124, and an inclined grate surface. The cells are placed back to back, and a feeding hole above is common to both sets. They are top, back, and direct-fed. The outlet flue is placed at the front over the grate, so that all objectionable fumes shall pass over the grate and become mixed with the gases. The gases from each cell unite in the combustion chamber where a steady heat of over 2,000° Fahr. can easily be maintained. Air boxes at the sides of the grate and a steam blast provide a good circulation. The steam blast is a special feature of this type. A unique feature is the centrifugal dust-catcher whereby the escaping gases are robbed of the last atoms of dust. Fig. 125 is a plan view of a 6-cell destructor.

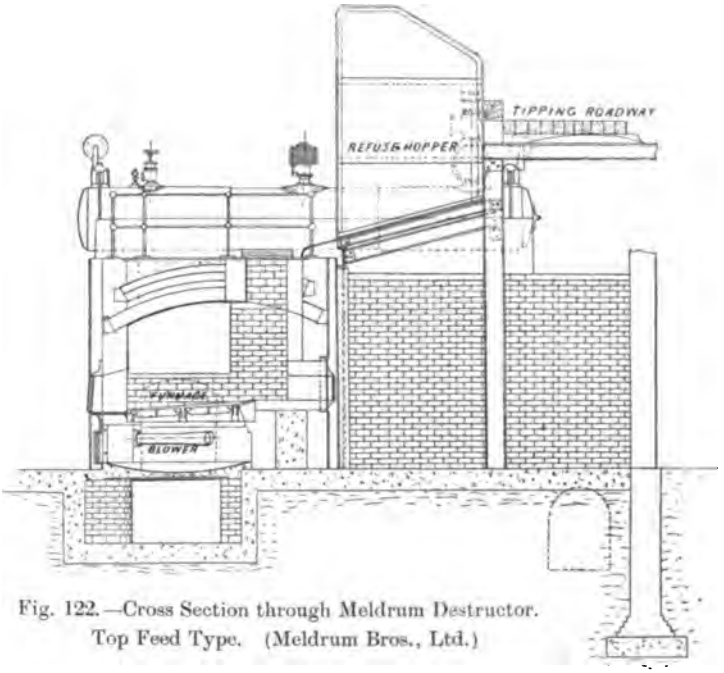


Fig. 122.—Cross Section through Meldrum Destructor. Top Feed Type. (Meldrum Bros., Ltd.)

Beaman and Deas.—This destructor is of the high temperature type, and was one of the first made. The general design is that of two cells with inclined drying hearths on which the refuse is dropped. One combustion chamber is common to two cells, in which the gases mingle. Forced draught is provided by steam-driven, or electric fans.

The destructors of the present day are so remarkably efficient in the utilisation of the commonest rubbish, town's refuse, and slack, that they have been adopted for steam raising in numerous electricity works, notwithstanding

that much prejudice existed not long since against this application. In 1902, destructors had been adopted in 160 towns in Great Britain and Ireland, and forty-five of these installations had been combined with electricity works, and judice against destructors as a nuisance was born in the days of low temperatures. Neither

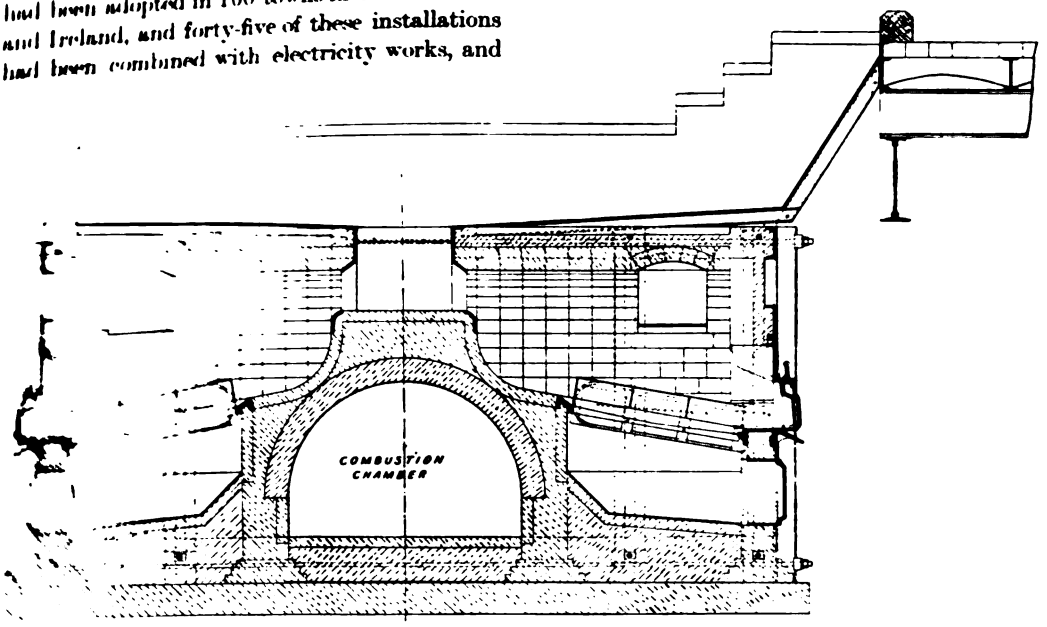


Fig. 124.—Horsfall Destructor. For Steam Blast only. (The Horsfall Destructor Co., Ltd.)

the actual destroying capacity of these was estimated at 1,400 tons of refuse daily. This is due to the change from low to high temperature destructors. The first destructor erected by Mr A. Fryer in 1876 is still in use, though now fitted with forced draught. The old pre-

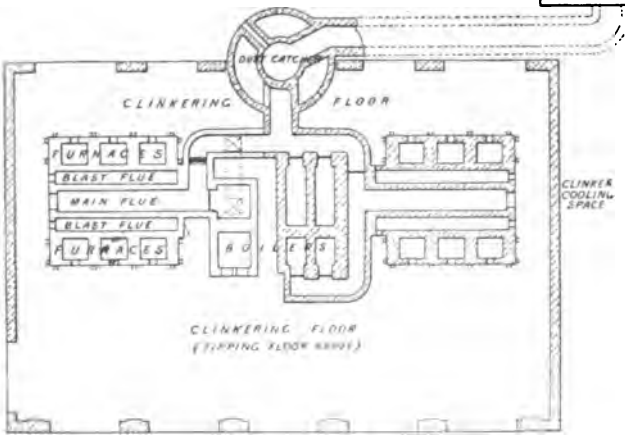


Fig. 125.—Plan of 6-Cell Horsfall Destructor. (The Horsfall Destructor Co., Ltd.)

was the temperature of the escaping gases high enough for use in a steam boiler.

Mr W. F. Goodrich has given some figures that show strikingly the differences in the high and low temperatures. The lowest on record is an old Beehive destructor at Nelson, with a temperature of 725° Fahr., the highest a Meldrum Simplex, at Walker-on-Tyne, of 3,000° Fahr. Records of 2,000° Fahr. are numerous.

The calorific value of town's refuse varies. Mr Goodrich gives the following:—

Nelson 1·95, Darwen 1·71, Lancaster 1·63, St Helens 1·54, Blackburn 1·297, Liverpool 1·173, Canterbury 1·58, Hackney 1·415, Wandsworth 1·24, Fulham 1·15.

The sheets appended give some remarkable efficiencies by destructors.

RESULT OF TEST CARRIED OUT AT THE BOROUGH OF PRESTON DESTRUCTOR AND TRAMWAY POWER STATION ON ONE UNIT (No. 2), 5TH APRIL 1905.

Type of Plant	Meldrums' Patent Simplex Regenerative Refuse Destructor	
	No. of Grates	4
	Area	100 square feet (total).
	Boiler, Lancashire	30 ft. × 8 ft.
	,, Heating Surface	986 square feet.
Results	Total Refuse to be Destroyed	
	Guarantee	40 tons in 24 hours.
	Refuse destroyed in 24 hours	66 tons 19 cwts.
	Water Evaporation from and at 212° per lb. of Refuse	1·7 lb.
Observations	Duration of Test	8¾ hours.
Refuse	Total Refuse fired during Test	24 tons 8 cwt. 1 qr. = 54,684 lb.
	,, ,, ,, per hour	6248·6 lb.
Clinker	Total Weight of Clinker, 30·3 %	16,579 lb.
Ash	,, ,, ,, Ash from below Grate, 2·9 % of Refuse fired	1,624 lb.
Flue Gases	Carbonic Acid Continuous Samples	12·13 %.
	Oxygen	6·46 %.
	Carbonic Oxide	·15 %.
Flue Temperatures	Combustion Chamber (by Watkins Indicator) (average)	2,288° Fahr.
	,, ,, (maximum)	2,700° Fahr.
	Downtake (average)	1,310° Fahr.
	Side Flues ,,	861° Fahr.
Air and Draught	Temperature of Air entering Regenerator	60° Fahr.
	,, ,, leaving ,,	470° Fahr.
	Ashpit Pressure (average)	2·8 inch of Water.
	Suction Draught at Chimney Base	·75 inch of Water.
Feed Water	Delivered to Boiler per hour	8857·1 lb.
	Temperature of Feed to Boiler	222° Fahr.
Steam	Gauge Pressure	166 lb. per square inch.
	Absolute Pressure	181 lb.
Economiser	Green's	288 tubes.
	Weight of Feed entering per hour	8857·1 lb.
	Temperature of Feed entering per hour	50° Fahr.
	,, ,, leaving	222° Fahr.
	,, Flue Gases entering Economiser	648° Fahr.
	,, ,, ,, leaving ,,	320° Fahr.
Deductions	Weight of Refuse fired per sq. ft. of Grate per hour	62·49 lb.
	Feed Water evaporated per lb. of Refuse	1·41 lb.
	Equivalent Evaporation from and at 212° per lb. of Refuse, Boiler and Economiser combined	1·7 lb.
	Electrical Output, B.O.T. Units	2,446.
	,, ,, ,, ,, per hour	279·54.
	,, ,, ,, ,, per ton of Refuse	100·24.

REFUSE DESTRUCTORS, "MELDRUM" SYSTEM.

		Water evaporated per lb. of Refuse from and at 212° Fahr.	Electrical Output, Units per Ton of Refuse.
		lb.	
Stoke-on-Trent	15 hours' test	2·6	108·1
Nelson	8 ,, ,, (maximum)	2·35	...
,,	5 weeks' ,, (average)	2·12	104·0
Todmorden	11 hours' ,,	2·09	...
Burnley	one ordinary week's result	2·00	...
Bangor	7¼ hours	1·98	...
*Cambuslang	6 hours' test	1·92	...
Woolwich	24 ,, ,, {by the National Boiler Insurance Co.}	1·917	100·0
Preston	9 ,, ,,	1·7	100·24

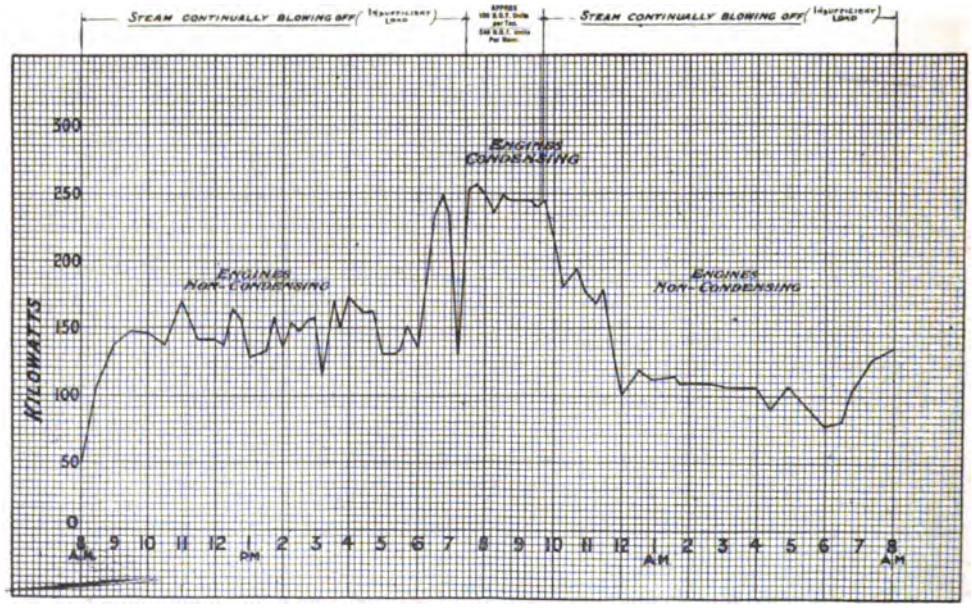
Figures certified by Engineers and other responsible Officials.

* Temperature of Combustion Chamber at start = 750° Fahr.
,, Feed Water, 46° Fahr.

WOOLWICH DESTRUCTOR AND ELECTRICITY STATION.

Chart giving load in kilowatts during a twenty-four hours' run. Test carried out by the National Boiler and General Insurance Co., Ltd.

Type of Destructor.—Meldrums' Simplex Regenerative (3 grate).
Type of Boiler.—Babcock & Wilcox, 1,827 sq. ft. heating surface. Superheater, 227 sq. ft.



Total Refuse Burned in 24 Hours 24 Minutes . . 63¼ Tons.
Average Rate of 2·6 Tons per Hour.

NOTE.—While the engines were running non-condensing, *i.e.*, when the load was very light, the boiler was continually blowing off.

The electrical output per ton of refuse during the two and a half hours of maximum load was just under 110 B.O.T. units, representing during that period a total output per hour of 245 B.O.T. units.

Total evaporation from and at 212° 1·917 lb. of water per lb. of refuse.

 Feed water delivered to boiler per hour, 950·4 gallons.

Detail Drawings.—Drawings that contain all the information required by the men in the shops for the carrying through of the work they represent. They embody all the separate parts of a mechanism, which are often indicated only by bare outlines in the general drawings of the complete mechanism. They are drawn to a large scale, or to actual size; and are, or should be, also dimensioned fully, down to the minutest detail. There is much improvement apparent in this respect over the older drawings sent out into the shops. It is largely due to the cheap multiplication of sun-prints, and partly to the greater sub-division of tasks in the shops, which renders the accuracy of all details essential if expensive fitting is to be avoided. In a perfect drawing, nothing whatever is left open to doubt, necessitating inquiry of foreman or draughtsman. Materials and

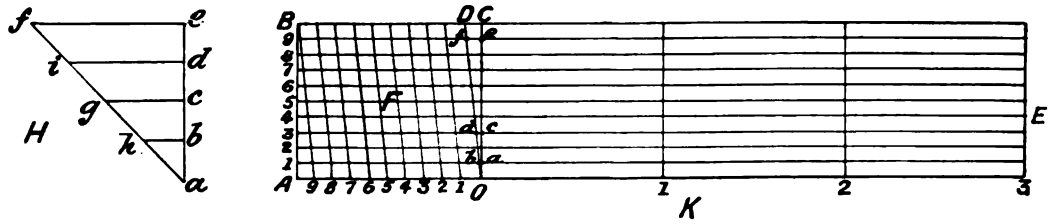


Fig. 126.—Diagonal Scale.

dimensions, even to those of the smallest screw, pin, or washer, are clearly given in writing.

Detector Galvanometer.—A cheap form of galvanometer usually combined in a case with a pair of dry batteries, and employed for indicating the passage of an electric current, without regard to its measurement.

Detrusive Tools.—Punches and shears, in which the action may or may not be combined with a slight amount of real cutting. The squeezing predominates so much that the material is greatly distressed, and slight surface cracks and roughnesses are produced which render these processes inadmissible in high-class work.

Development.—This denotes the obtaining of the envelopes of solid or hollow bodies on a plane surface. Excepting in a few examples such figures cannot be obtained by calculations, but must be produced by systems of intersecting lines deduced from points of equal division. They have their principal applications in the work of the boilermaker, and plater, of the coppersmith, and tin-man.

Diagonal Scale.—A diagonal scale is an ingenious device for representing three dimensions such as units, tenths, hundredths; yards, feet, inches, and so on. The principle on which it is constructed is based on Euclid, vi. 2. For it follows (in Fig. 126, H) that if *a-c* is half of *a-e* then *c-g* is half of *e-f*; similarly *b-h* is one-fourth, and *d-i* three-fourths of *e-f*. If *a-e* were divided into ten parts, it would be possible to read tenths, and if at the same time *e-f* represented a tenth of a unit, say one-tenth of an inch, we could read tenths of a tenth, *i.e.*, hundredths of an inch.

This, then, is the principle developed in Fig. 126, K, which represents a diagonal scale reading inches, tenths, and hundredths of an inch. The line A3 is divided into 4 inches, and the first of these is divided into tenths of an inch along AO and BC; these points are then joined by diagonal lines as shown. Then by the principle explained above, *ab* is one-tenth of CD, *i.e.*, one-tenth of a tenth of an inch, or $\frac{1}{100}$ in.; $cd = \frac{3}{100}$ in., $ef = \frac{9}{100}$ in. It is therefore clear that a measurement such as $3\frac{54}{100}$ in. or 3·54 in. would be shown by EF, for this equals 3 units, 5 tenths to the foot, of F, and 4 hundredths.

Diagonal Stays.—Boiler stays which connect the end plates with the barrel, and are therefore set at an angle with both. Their function is to stay the end plates, and they are alternative to the use of barrel stays which run parallel with the boiler barrel. They interfere less than the last-named with the cleaning of the boiler. They are in two forms; the bar or

palm stay, Fig. 127. and the plated, or gusset type. The first is riveted to the barrel with a flat extension (the palm); and to the end plate, either with a screwed end, nutted inside and out, or with a forked end and cotter pin to a tee bolted to the plate. The second are attached with angles riveted to the gusset plates. Diagonal stays are in tension. Their stress bears the same relation to the stress on a horizontal stay that the angle of the stay does to the horizontal, thus:—

Find the cross sectional area a of a direct stay to support the same area of plate as the diagonal one. Multiply that by the length L of

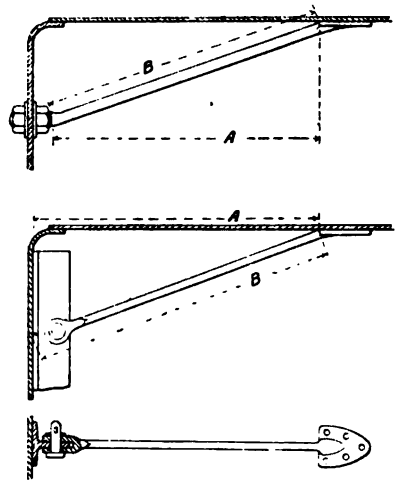


Fig. 127.—Diagonal Stays.

the diagonal stay, and divide by the horizontal length l to obtain the area A of the diagonal stay, thus:—

$$\frac{a \times L}{l} = A,$$

or, trigonometrically,

$$D = \frac{P}{cos.\ a}$$

where P = pressure against the area of the end plate supported by the stay; a = the angle which the stay makes with the direction of pressure against the plate; D = the tension on the diagonal stay. Or, graphically, let the distance A, Fig. 127, represent the pressure on the area of the front plate supported by the stay; then the magnitude of the resultant will be measured by the length of the diagonal B.

Dial Gauge.—A pressure or vacuum gauge in which the pointer moves round a face of disc or dial form.

Diamagnetic.—Whilst some metals, as iron and steel, are attracted to the poles of a magnet, a few substances, zinc, antimony, phosphorus, &c., are repulsed. These are said to be diamagnetic.

Diameter.—A diameter is a line which passes through the centre of a curvilinear figure, and terminates each way in the circumference. In the circle all diameters are equal, and an infinite number of them may be drawn.

Diametral Pitch, or **Diametrical Pitch.**—The basis of this is the number of teeth in a wheel, referred to 1 inch in diameter of the pitch circle. It denotes the number of teeth in a gear, divided by the diameter. It is therefore a ratio. If a number of equal lengths of rod are cut off corresponding with the number of teeth in the wheel, but of such a length that they will make up the pitch diameter, the length of each one will equal the diametral pitch. This pitch is the unit for the dimensions of the teeth in this system, just as the circular pitch is the unit in the circular pitch system.

In the diametral system the number of teeth in a wheel to 1 inch diameter of the pitch circle is the diametral pitch. Thus, if a wheel has twenty teeth, and its pitch diameter is 4 in., it has five teeth for each inch of diameter, hence the diametral pitch of the wheel is 5. The advantage of this is its simplicity, the pitch diameter being the basis to which the pitch must conform. Even diameters are therefore available.

The relation of diametral to circular pitch is that of the diameter of a circle to its circumference. Thus $\frac{1}{3{\cdot}14159} = {\cdot}3183$; ·3183 is therefore the diameter of a circle the circumference of which is 1. So that if a circular pitch = 1, the corresponding diametral pitch is ·3138; and if a diametral pitch = 1, the circular pitch corresponding is 3·14159.

Diamond.—A prefix in frequent use. A diamond shape in chequering is a rhombus, and the rhombus is the figure which is understood whenever a diamond or a *lozenge* pattern is

mentioned. A diamond point is a turning tool having one, or two cutting edges having rhomboidal relations in plan. A diamond pass denotes a rolled section having the shape either of a rhombus, or a square. But it differs from a box

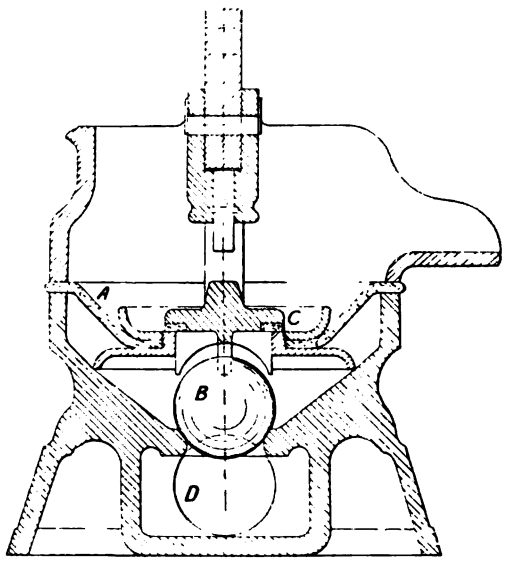


Fig. 128.—Diaphragm Pump.

pass, in the angles lying respectively parallel with and normally with the axes of the rolls. A diamond drill is one having diamonds set round it to form the cutting edge; *see* **Bore Holes**, Vol. III., p. 32. Diamond tools are also used for turning **Grinding Wheels**.

Diaphragm.—A distance piece which maintains two parallel plated girders at a distance apart.

liquids of a dirty nature, and containing mud, sand, gravel, &c. In Fig. 128 the diaphragm A of rubber is pulled up and down by the forked holder connected to a lever, the joint of which is seen above. As the diaphragm rises, the fluid is sucked in through orifice D, the rubber ball B lifting, and on the down stroke B closes, and the valve C opens, allowing free passage above, and over the shute. Sometimes the valve B is made of metal.

Die Forging.—*See* **Forging Dies.**

Dielectric.—Any substance separating two electrical conductors of opposite polarity. A dielectric may be composed of air, which offers the highest resistance to inductive effect. But any material having a high resistance to inductive action between charged conductors is dielectric or insulating. Thus the rubber, paper, &c., coverings of insulated cables are usually referred to as the dielectric. *See* **Insulation.**

Die Making.—*See* **Forging Dies.**

Die Nut.—A solid screwing die, having a square or hexagonal body outside, and used for finishing threads to size either in machine or by hand. It is often useful for running down studs or bolts that have become damaged on the threads.

Dies, or Screwing Dies, Die-Stocks.—These have always been the subject of much compromise in design, due to the difficulty of combining good cutting with good guidance, and sufficient clearance. The difficulty is mainly owing to the influence of the depth of thread. When dies commence to cut they operate on a diameter, *a*, Fig. 129, A, equal to the top of the

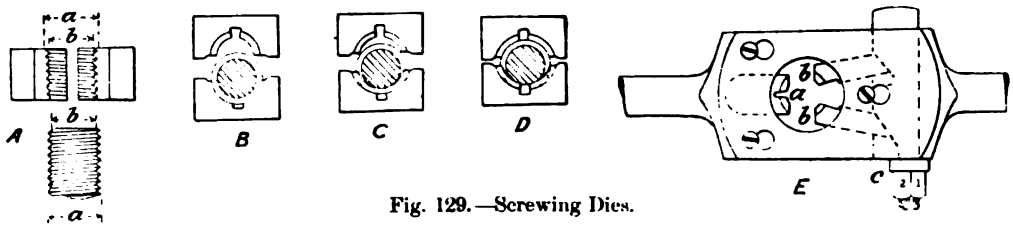


Fig. 129.—Screwing Dies.

Diaphragm Pump.—A type which instead of a plunger reciprocating in a barrel, has a flexible diaphragm which is moved up and down to cause the suction. It is therefore specially suited for handling liquids or semi-

threads; when they have finished, the same edges that started, finish cutting at the bottom of the threads, *b*. This difference is considerable. This also interferes greatly with suitable provision for clearance, and it is further compli-

cated by the fact that dies in which the angle of thread is fixed have to cut a thread the angle of which varies as the depth increases. And if the attempt is made to give much clearance, and ensure sweet cutting from beginning to finish, all power of guidance is lost, because the cutting edges have to be reduced. The threads deeper, their curvature coincides with the bar at the commencement, and the guidance is perfect, but the cutting capacity is *nil* at first. But at the termination the cutting is at its best. The best compromise is as in C, where cutting takes place throughout, with moderate control.

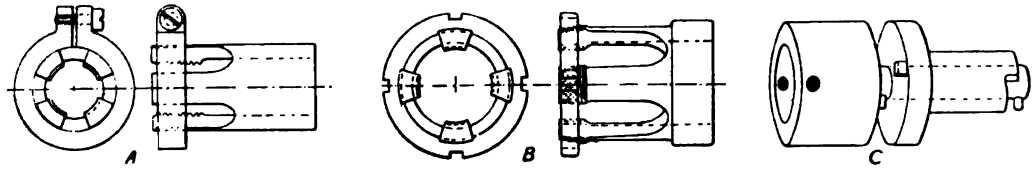


Fig. 130.—Dies for Capstan Lathes.

diagrams illustrate what takes place when common dies are cutting a thread.

Fig. 129, B, shows impossible dies. Their curvature coincides with that of the finished thread, and therefore they would lack guidance at the beginning, cutting merely by the extreme corners, and at the end they would

In the best dies the notches are widened, and the curved portions narrowed, by which the labour of cutting is reduced. Or, as in the Whitworth form, the functions of guidance and cutting are performed by separate elements, Fig. 129, E, in which *a* is a fixed guide, and *b b* the cutters which are adjustable by the special

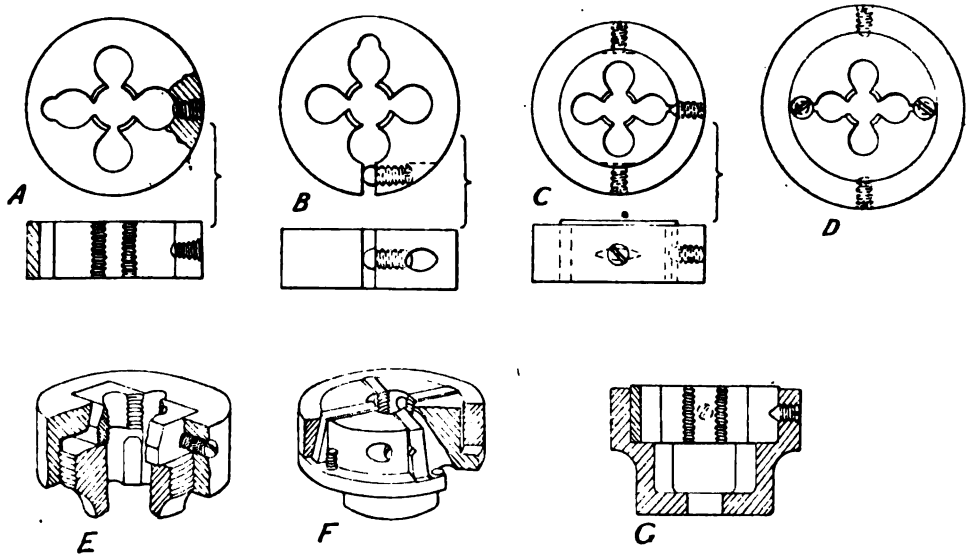


Fig. 131.—Split Dies.

not cut at all, but simply embrace and squeeze the thread. The capacity for cutting, and clearance depends on curvature, and these capacities are obtained by cutting dies over a hob one thread deeper than the screw to be cut, as in C. If they are cut as in D, two cotter bolt *c*. In these, the fixed die cuts at the commencement, and afterwards one of the movable dies, the other cutting on reversal. They are cut over a hob two threads larger than the screw to be cut.

Dies used on Capstan Lathes.—In considering

the screwing dies used on capstan lathes, screw machines, and automatic screw machines, we find some resemblances in form to those employed in die-stocks, described below, but modifications in shape and method of gripping are introduced to suit the nature of the work. Two types, which, however, are not used by hand, find extensive employment in machine work. Fig. 130, A and B, called spring dies, are closed in by nose rings, the first being split and squeezed in with a screw, the second acting by a tapered thread on the nose. Very fine variations in size can be effected in this manner. The

Opening Die-heads

will be treated under that title.

Circular dies are held, for screw machine work, either in plain holders having a shank to fit in the turret, or else in "releasing" die holders C, which allow of cutting to exact lengths. The holder slides in a sleeve gripped in the turret, and clutch teeth on the sleeve end are arranged so that as the die reaches the shoulder, the clutch allows it to slip, and rotate with the work until the machine spindle is reversed, when the horns seen between the shoulders of die and sleeve engage, and hold the die from revolving, so that it runs off the thread.

Circular dies, with means of adjustment embodied, are very efficient tools, cutting threads at a single run down. Various designs are shown, Fig. 131, in each of which the die is split, the amount of spring thus introduced being utilised to close in or open out the dies sufficiently. At A, a tapered screw is used to force the split portion apart, or to let it close in; at B a similar effect is obtained by a screw at right angles to the split. C is a type fitted within a collet (which is held in the die-stock), one pointed screw serving to open the die, while the two lateral ones close it inwards, each being slacked back when adjusting. D has two tapered screws in the split (which divides the die-halves right across) and two pressing on the body, enabling expansion and contraction to be effected with ease. A rather different design, with the die-halves of rectangular form, is given at E, the dies being adjusted to and from the centre by screws pressing on the ends. These are let into a collet, which is screwed upon the guide, the latter affording a bed for the dies, which are kept from rising by their bevelled edges lying inside the collet.

There are numerous dies with flat chasers inserted, which cut the threads, this being

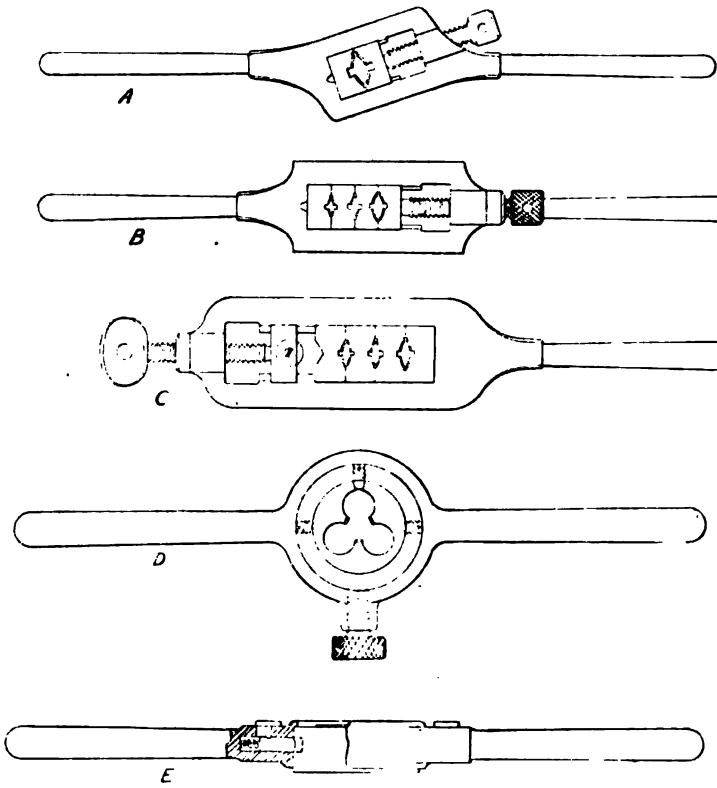


Fig. 132.—Die-Stocks.

economical of steel in large sizes, and permitting of re-grinding by removal. In example F the four chasers fit in grooves, and are fixed firmly by side-setting screws, entering vee-grooves as seen. The outer ring is coned inside to match concentric chuck jaw movement, enabling the dies to be lifted off the thread without the trouble of screwing back. G shows a collet having a guiding hole formed in it, a variation on the style seen at E.

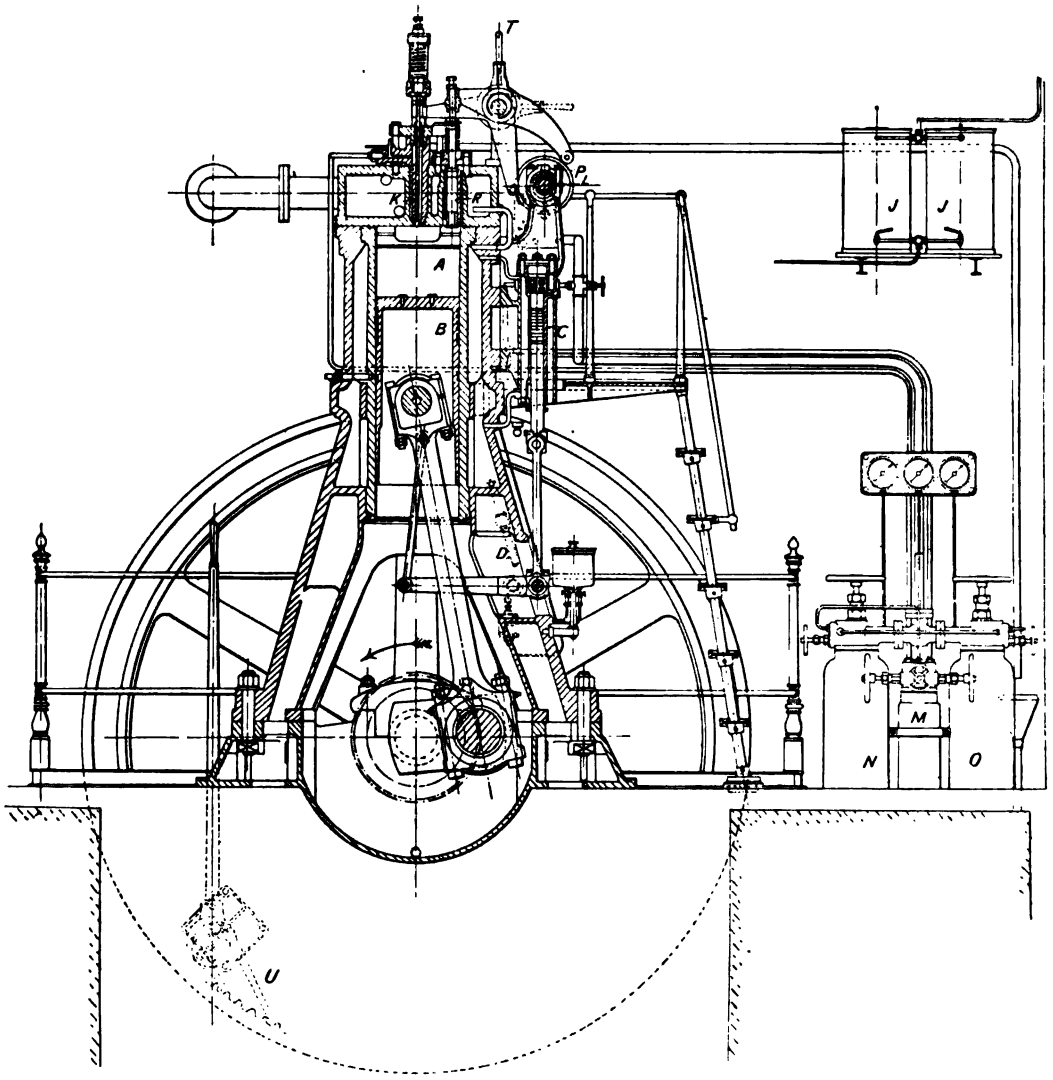


Fig. 133.—Diesel Engine. Transverse Section.

the bevelled ends of the chasers, and being pulled down by screws passing up through the shoulder of the body piece, closes the chasers in, or alternatively lets them outwards when raised. One type of die-stock gives a simultaneous radial motion to the chasers, like a

The methods of holding dies in the hand-stocks differ according to the shape of the dies. In the flat ones made in halves, Fig. 129, either of the fittings shown in Fig. 132 at A, B, or C is adopted, the dies sliding by vees, to retain them in position. The closing-in is

effected by the screws seen, that at A being turned by a podger, at B by a knurled body, and podger, at C by the fingers also, with the help of a podger when necessary. C is used especially for gas-threads, several dies of different sizes being fitted in the same body. This view also shows the inclusion of a wheel for cutting off pipe.

Circular dies are usually held in their stocks by set screws, passing through the stock and pressing by a point in a countersink in the die or collet, D. A more rapid mode of locking is secured by having spring catches or plungers, as at E, which are drawn back by the heads above for the insertion of the die, and then released.

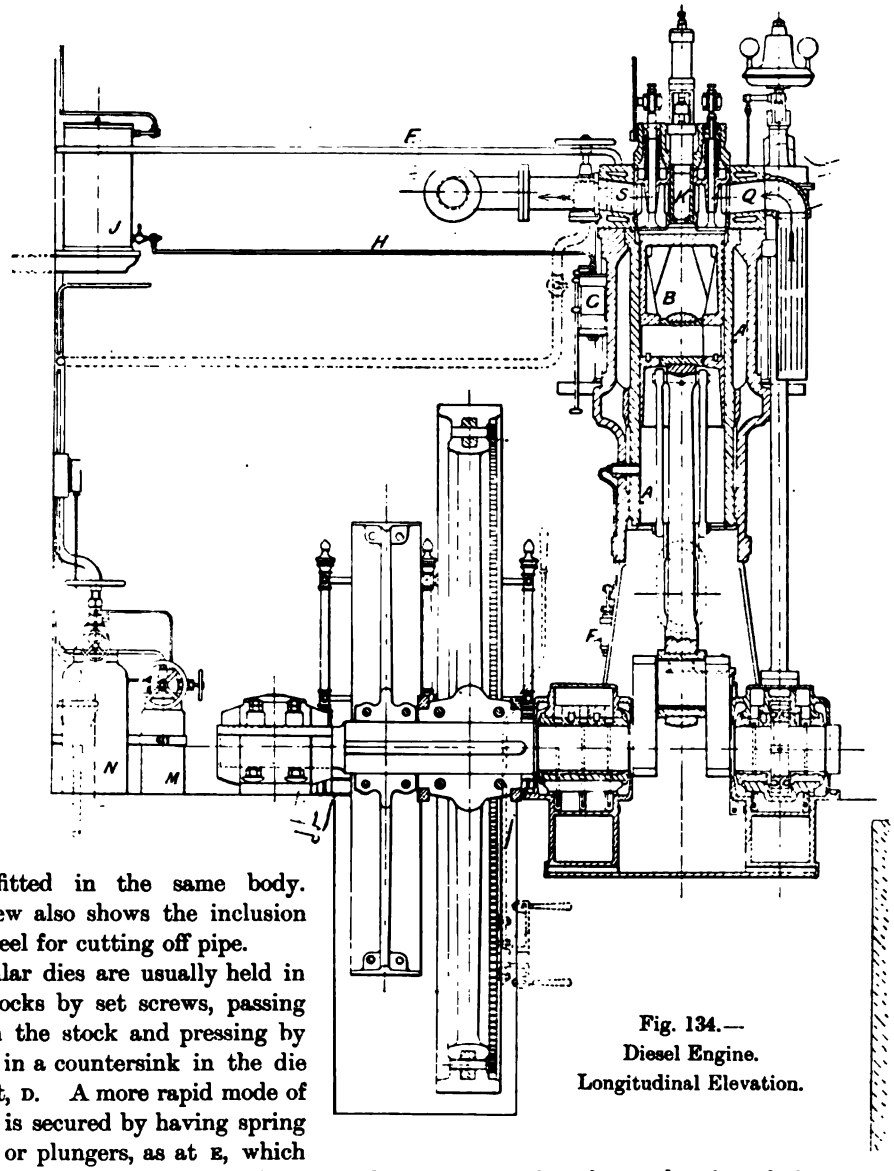


Fig. 134.—
Diesel Engine.
Longitudinal Elevation.

Diesel Engine.—A vertical internal combustion engine working with oil on the four-stroke cycle, as follows:—The first stroke takes in air alone at atmosphere pressure and temperature. The second stroke compresses this to 35 atmospheres = 500 lb. per square inch, and to a temperature of about 1000° Fahr. The third stroke is the working one. In the first part of it the combustion of the fuel is carried on at constant pressure, during a period which is determined by the amount of oil sprayed in, which quantity is controlled by the governor. The second part of the stroke is approximately

an adiabatic expansion. The fourth stroke exhausts the gases.

Figs. 133, 134 show a vertical single cylinder Diesel engine of 70 B.H.P., by the Vereinigte Maschinenfabrik Augsburg und Maschinenbaugesellschaft Nürnberg A. G. Augsburg, the details of which are as follows :—

The cylinder A, water jacketed, is fitted with a trunk piston B, having a connecting rod of marine pattern. The cylindrical portion of the jacket is an extension of the **A** standard bolted on the base plate, and bored to receive the cylinder. The valve casing at the head forms the water jacket at the upper end of the cylinder. The jacketing also includes the air pump, C, Fig. 133, pipes connecting the pump jacket with the cylinder jacket. The water enters the jacket at D, passing upwards through both cylinder and air pump jacket to the cylinder cover, and thence by the discharge pipe E, Fig. 134. The piston B has seven rings, six near the top, and one lower down to pass the lubricating channels. The lubrication is effected by the pump F, Fig. 134, the lubricant entering the cylinder at five or six openings in a horizontal plane below which one of the piston rings passes.

The petroleum fuel pump is seen at G, Fig. 134, at one side of the cylinder. It receives the oil through the pipe H from the filtering tanks J, and is connected by another pipe to the fuel valve K above the cylinder. The pump plunger is worked by a crank pin on a disc at the end of the cam shaft L, Fig. 133. In the fuel valve K the combustible is mixed with compressed air, and then introduced into the working cylinder. Air is compressed by the air pump C. Its plunger is driven by the connecting rod rocking levers and connecting links from the small end of the connecting rod, as seen in Fig. 133. In the earlier Diesel engines the pump took its air directly from the atmosphere, but by the adoption of the system just described, the air pump is reduced to about $\frac{1}{14}$th of its original size.

Compressed air is also used for starting the engine. The air is compressed by the pump C and stored in the reservoirs M, N, and O ; O being a reserve reservoir. All the operating valves are contained in the cylinder cover, and all are opened by cam discs or wrist plates P on the shaft L, operating the levers seen above, and all are closed by springs. The shaft L makes half as many revolutions as the crank shaft, being driven by a vertical shaft and gears. The valves are the fuel valve, or oil sprayer K, already mentioned ; the air pump suction valve Q, the starting valve R, the exhaust valve S. T is the handle by means of which the reversing levers are placed in the starting position. The crank shaft has three bearings fitted with ring lubricators. The flywheel is in halves, and includes a toothed ring, Fig. 134, in which two ratchet pawls work, Fig. 133, U, for bringing the engine over dead centres for starting.

The features which distinguish the Diesel engine from other types are the high compression of the air to about 500 lb. per square inch with a temperature of 1000° Fahr., so that the fuel burns at once on injection without requiring an igniting device. The gradual injection of the fuel into the heated air by means of an air blast from 100 lb. to 150 lb. pressure per square inch higher than that already in the cylinder. And lastly the gradual and complete combustion of the fuel, in place of the explosive combustion of the ordinary engine.

Difference Gauge.—A synonym for **Limit Gauge.**

Differential Arc Lamp.—An arc lamp controlled in feeding the carbons forward as they are consumed, by the differential action, or balancing against each other, of two opposing solenoids. These are so arranged that whilst the one magnet, having its coils connected in series with the arc, tends to lengthen it by pulling apart the carbons, the other, being placed as a shunt across the lamp terminals, tends to shorten it by bringing the carbons together. The effect of these magnets being adjusted, the carbons may be kept at a fixed rate of feed, and so a constant length of arc and a steady light be secured. *See* **Arc Lamps.**

Differential Feed.—The feed of a boring bar by which the tool is traversed a definite distance during each revolution of the bar. *See* **Differential Gears.**

Differential Gears. — Denotes generally

toothed gears so designed that the rotation of the driver produces a minute difference in the rate of the last gear in the train. The applications possible are numerous and valuable. A particular application is that of **Epicyclic Trains.**

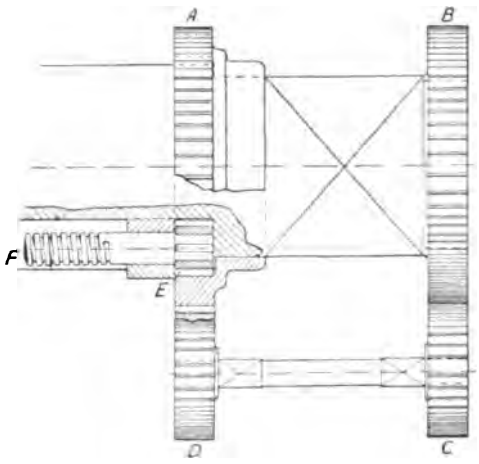


Fig. 135.—Differential Gears.

Fig. 135 illustrates a differential feed arrangement designed for a boring bar. The wheel A is an annular one with an equal number of teeth on the outside and inside, and it fits freely on a turned shoulder on the bar, being confined by a collar. The pinion E on the end of the feed screw gears with the internal teeth, and the pinion D with the external. B is a wheel fast on the end of the bar, and having the same number of teeth as A. C is on the same shaft as D, and has one tooth more than D (it might have two or three teeth more, the slight difference in number is the essential matter). For obviously if C and D were alike the wheel A would partake of the rotation of the bar, and the pinion E would not rotate at all. But the effect of the difference of one tooth in C and D is to cause D to lag behind C, and so cause the pinion to rotate through the space of one tooth, which it is able to do, because A being loose accommodates itself to the movement. The amount of feed imparted to the screw F which slides the boring head along the bar, equals during one revolution of the bar:—

$$\left(\frac{\text{pitch of screw F}}{\text{number of teeth in pinion E}}\right) \times \frac{\text{number of teeth in A or B}}{\text{number of teeth in wheel D}}$$

Another differential gear is shown in Fig. 136, also applied to a boring bar. Here A and B are the differential wheels, A having one tooth more than B. C and D cast, or fitted as one, gear with A and B. The connection of these with the bar and the feed pinion is shown in the sectional view. B is keyed on a spindle E, which has its bearing in a bush F, to which bush A is fitted as a ring and secured with a screw key both to the bush and to the boring bar, turning therefore with the bar. A and B are thus independent of each other, excepting through the movement imparted from A to B through D and C. This differential movement is transmitted from B through the shaft E to the equal pinions G and H, H being on the end of the feed screw J. The difference in the numbers of teeth of A and B governs the movement of the screw. A will make the same number of revolutions as the bar, and the rate traverse of the head will be the more rapid, the greater the disparity in the number of teeth of A and B.

Differential Principle.—Signifies the taking advantage of some difference in dimensions, or relations of elementary mechanisms, to yield gain or loss in power, or to obtain a relative motion of some kind.

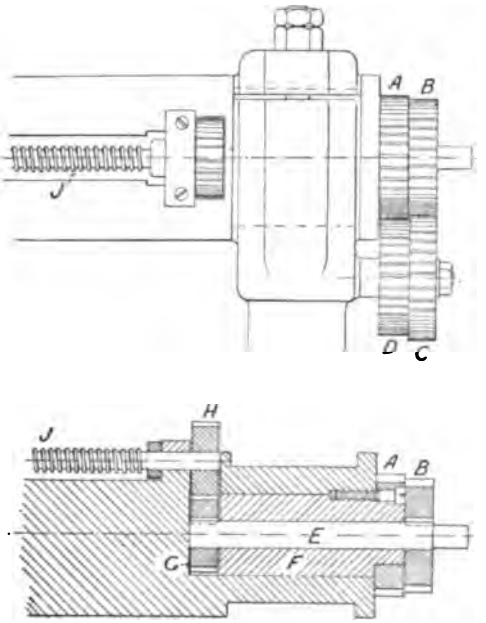


Fig. 136.—Differential Gears.

Differential Pulley Block.—A pulley block which consists essentially of two pulleys each of different diameter, secured upon the same axle, and provided with an endless chain and a falling block. Fig. 137 illustrates the principle: the chain is reeved as shown, and is made in links of uniform shape and pitch so as to fit recesses cast upon the peripheries of the pulleys in order to prevent slipping. The mechanical advantage is very great, and may be expressed thus: power applied to the chain A multiplied by the diameter of B = the weight lifted multiplied by half the difference between the diameters of B and C. Such a pulley block is self sustaining, *i.e.*, the load will not run down when the hauling chain is released, it being necessary to haul on the chain in the opposite sense in order to lower the load. The disadvantage of this appliance is the very low efficiency obtained, approximately 40 per cent.

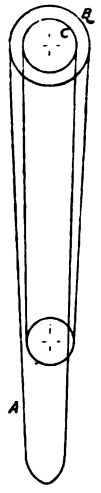


Fig. 137.—Differential Pulley Block.

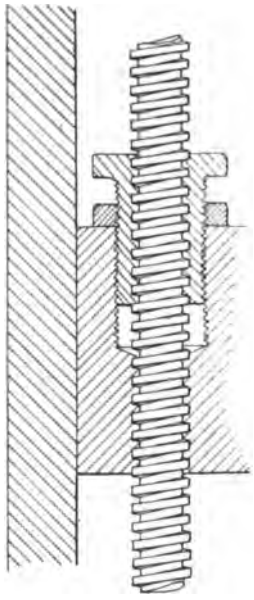


Fig. 138.—Differential Screw.

Differential Screw. — Applied to equal screws of right and left hand threads on the same bar, by the turning of which portions of mechanism are separated, or closed up. Also to the case of two screws of different pitches on the same rod for effecting either quick and slow movements, or mechanical advantages, or for locking purposes.

A common application of the differential screw is to lock nuts of special form for taking up the wear on the feed screws of planing machine tool boxes, Fig. 138. This takes the form of a circular nut, through which the feed screw passes, and it is threaded outside finely with about twenty threads to the inch, by which adjustments are made without risk of slip. The quick withdrawal of the tool slide of a lathe rest is a differential arrangement, the fine screw being used for the feeding movements, the coarse for rapid withdrawal in screw cutting, or when turning to a shoulder.

Diffusion. — Is the name given to the phenomenon observed when gases or liquids, which do not chemically combine, are brought into contact with each other. This phenomenon consists in their gradual interpenetration, so that even if there be a considerable difference in relative densities, the gases or liquids concerned eventually become intimately blended. This action thus takes place against the action of gravity, as may be shown by placing a jar of hydrogen above a jar of carbon dioxide. The latter gas is heavier than air, and considerably heavier than hydrogen, yet after a lapse of a short time the two gases are intimately mixed in both jars. The rate of diffusion of different gases is inversely as the square root of their densities.

Liquids which are miscible not only diffuse, like gases, when in contact, but this action takes place even when the two liquids are separated by a membrane such as parchment paper or bladder. Diffusion takes place in spite of the barrier. This is called *osmosis*. If a beaker filled with one liquid and closed with a membrane be submerged in a vessel containing another liquid, interdiffusion takes place, but one liquid will probably pass through the membrane at a greater rate than the other, sufficiently rapid may-be to burst the membrane. If this action increases the contents of the beaker it is called *endosmose*; if the contents are decreased the action is called *exosmose*.

Diffusion of Metals. — Metals melted together to form alloys possess a remarkable homogeneity, notwithstanding the liquation

which occurs in those having great differences in melting points. The steels and the gun-metals, for example, are of practically uniform texture. But metals diffuse among each other at temperatures far below their melting points. This is paralleled by diffusion occurring in saline solutions, and in the penetration of solid iron by carbon in the cementation process. In experiments by Sir W. C. Roberts-Austen, gold placed at the bottom of a cylinder of lead 3 inches high, and heated to only 200° Cent., or far below its melting point, diffused to the top in large quantities within three days. The subject is of interest, because it may lead to results bearing on the molecular changes which do undoubtedly occur in metallic structures.

Dimension Sawing Machine. — A machine using two circular saws on separate spindles, the frame for which is movable by a hand-wheel and worm gears to bring either saw to a definite height above the table. One saw is set and sharpened for ripping, the other for cross-cutting. A canting fence is usually fitted. The value of these saws lies in their capacity of adjustment to suit different depths of cut, useful especially in rebating and shouldering generally, in addition to the ordinary work of the two saws. They will thus often save the rigging up of blocking, and taking numerous direct measurements.

Diminishing Socket.—A short length of socket pipe having different diameters at the ends to connect two pipes of different sizes.

Dinas Brick.—A highly silicious brick used for Siemens furnaces, and prepared from Dinas rock found in the Vale of Neath in South Wales. It contains about 97 per cent. of silica, with traces of alumina, ferric oxide, and alkalies. About 1 per cent. of lime is generally added to serve as a binding material. The bricks are made of coarser texture for furnace roofs that are subjected to considerable variations in temperature than for those where it is more uniform. These bricks will withstand a clear white heat, but not contact with oxide of iron.

Dip Crank.—*See* **Crank.**

Direct Acting.—Signifies the transmission of the movement of the piston directly to a crank shaft. Also the travel of a slide-valve when equal to that of the throw of its eccentric.

Direct Casting.—The difficulties that arise in attempts to pour heavy castings direct from the blast furnace are due partly to the uncertain character of the product, partly to its non-homogeneous condition. All iron is better for remelting once or twice, for the same reason that the copper alloys are better if ingoted The cost of remelting may be avoided for a rough class of castings without sacrifice of strength, provided certain precautions are taken; but it cannot be expected that direct casting will ever supersede cupola practice, simply because remelting is necessary to render pig homogeneous and strong enough for the average run of cast work. But there is a large class of work for which direct casting might be well adopted: the heavier rougher kinds, as kentledge, tubbing, keel blocks, segments for tunnelling. The tunnel segments for the Great Northern and Strand Tunnel Railway, and some special castings for the King's Cross and Piccadilly line, were poured direct from the blast furnace, by Messrs T. Butlin & Co., Ltd., of Wellingborough.

To obtain good results it is necessary to pay regard to the slag, which shall partly purify the pig, by withdrawing as much sulphur as possible from the fuel, and this involves care in the selection of the coke, and of the limestone used as flux.

Direct Current.—Current obtained from a primary battery is always given with the same direction of flow, that is to say, the one terminal is always positive and the other negative. A dynamo generates current alternating in direction, but this may be taken from its terminals as direct, or current flowing continuously in the same direction around the conducting circuits, by commutation. *See* **Dynamo.**

Direct Current Dynamo.—A dynamo having a commutator for converting alternating to unidirectional currents.

Direction of Current.—Electricity is said to *flow* along a conductor, leaving its source at the positive terminal, flowing round its restricted circuits, and re-entering its source at the negative terminal.

It is often necessary, as for the proper connection of continuous current arc lamps, motors or instruments, or the charging of accumulators,

to ascertain the direction of flow of current in an unknown circuit. An easy method of testing this is shown in Fig. 139, where A, B are the mains to be tested, w^1, w^2, w^3 the copper wire temporary connections, S a switch, and a glow-lamp seen below w^2, suitable for the known voltage. The vessel V may be a battery jar holding, say, half-a-pint of very dilute sulphuric acid, or a salt or soda solution. Two lead plates are hung in the solution, but must not touch each other. The wires being connected to the mains, S is closed, the lamp lighting up, and the current is allowed to pass for a few moments. On switching off, examine the lead plates, when one of them will be seen to have become of a brown

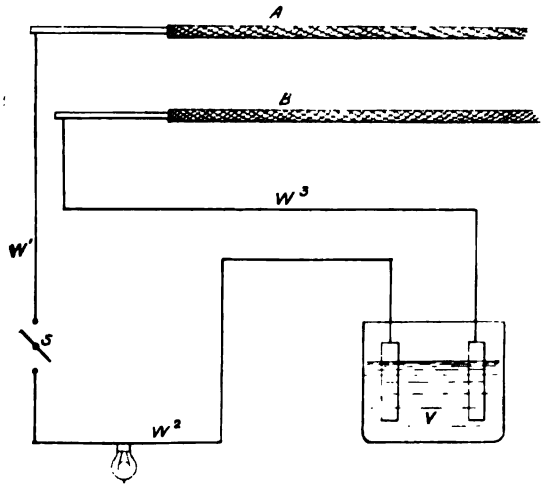


Fig. 139.—Diagram of Direction of Current.

colour in the solution. In the cable to which this brown plate is connected, the current is flowing in a *positive* direction.

Another simple method of finding the direction of current in a conductor may be given, requiring only what is generally available to the engineer. Take a strip 3 in. long by 1 in. wide of the blue-print paper on which engineers' drawings are copied. Wet this thoroughly in clean water, and lay it along a strip of wood. Now take two small copper wires, and, connecting an end of each to the live cables (as w^1, w^3), touch their loose ends lightly to the wet blue paper, keeping them 2 inches apart. In a moment a *white* mark will appear at one point of contact, and this wire is shown to be connected with the *negative* cable.

Direct Processes.—Relates to the manufacture both of malleable iron and steel. Neither of these are of much commercial importance by comparison with the immensely larger volume turned out by indirect processes.

The Catalan furnace or forge is a direct process furnace, in which ore is reduced by charcoal to malleable iron. The losses of iron in rich slags, which are ferrous silicates, $2FeOSiO_2$, and the large consumption of charcoal are serious drawbacks. But all wrought iron formerly produced in the world, and all still produced among savage nations, is obtained by direct reduction from the ore.

Probably the earliest attempt made commercially to produce wrought iron directly from the ore was that of W. N. Clay. The Siemens rotating furnace is only of interest from the name of its inventor, for it has followed other attempts into the limbo of oblivion. A process of some importance is the American Bloomery employed in the Eastern States of America, where a finely divided magnetic ore is obtainable, and also charcoal. It is only suited to local conditions, and is wasteful and costly.

The direct processes for the production of steel have little more than an historic interest. They include the native furnaces of India and Africa, in which soft iron, or steely iron can be produced by varying the proportions of the charge; the Catalan, also producing soft iron or steely iron, and some others.

Disc Crank.—*See* **Crank.**

Disc Feed, or **Bowl Feed.**—A device for varying the feeds of some machine tools. It comprises a disc driven at a constant speed, which actuates a smaller disc in contact with its face. The latter is capable of radial adjustment relatively to the larger disc, so that its rotation is more rapid the farther it is receded from the centre, and in this way the rate of rotation of the feed rod on which it is keyed is varied.

Disc Grinder.—A grinding machine in which, instead of solid wheels, steel discs are used, having emery or other abrading material cemented on in the form of sheets. Two great advantages are thus obtained—the speed of

rotation may be doubled with perfect safety, enabling faster cutting to be done; and perfectly flat surfaces are obtained on the work, owing to the truth of the discs. These machines are therefore largely used for finishing flat faces, such as those of nuts, cotters, keys, brasses, forks, glands, levers, &c. The grinding is often performed more quickly than milling and shaping, and it is not necessary in many cases to clamp the piece, but it is simply pushed up by hand.

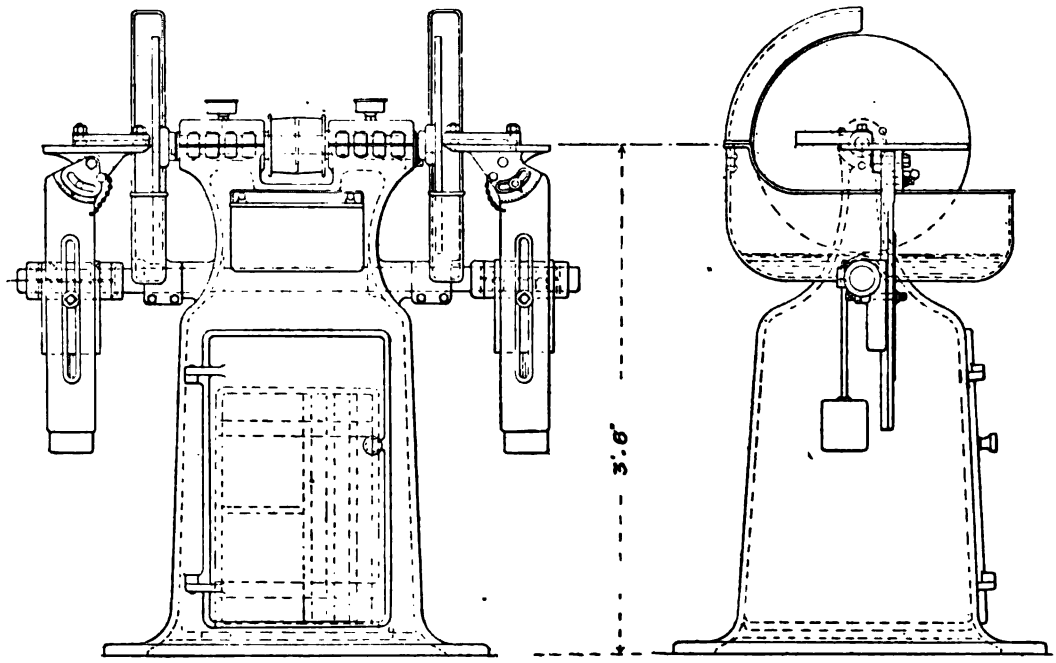


Fig. 140.—Disc Grinder. (Cunliffe & Croom, Ltd.)

Fig. 140 is a typical disc grinder by Cunliffe & Croom, Ltd., having discs 18 in. diam. by $\frac{9}{16}$ in. thick. A spiral groove is turned on the faces, so that the grinding cloth stands up in a series of ridges, promoting rapid cutting, and affording clearance for the dust. The two rests are attached, through the medium of a slotted bar, to a stiff shaft held in the machine body. The slots allow of adjustment for height of table. The tables are pivoted so that they may be angled for bevel grinding, a graduated arc indicating the setting. When the tables are set at right angles, a taper pin is used to fix them; this pin is attached to a chain to prevent its being mislaid. A protractor strip is fastened on the surface of each table, to control pieces which have to be ground to angles, such as nuts, cotters, &c. Dust collectors are fitted to the discs, with water in the bottom portion, so that the dust is caught. A water trough is screwed to the front of the frame so as to be within convenient reach of the operators. The spindle makes 1,800 revolutions per minute. The machine base is formed into a receptacle for discs, &c.

The cementing press is seen in Fig. 141 being simply a screw press to force the sheets, after glueing, into intimate contact with the discs; a spare set of the latter are provided, which may be in the press while the others are in use.

More elaborate machines than this are constructed having micrometer feed to the table carriers, so that repetition work can be produced with ease. Various clamping devices

are also fitted, sometimes shaped specially to grip awkward pieces, which cannot be held in the hand firmly. The type of machine lends itself admirably to direct motor driving, with the motor mounted between the bearings in

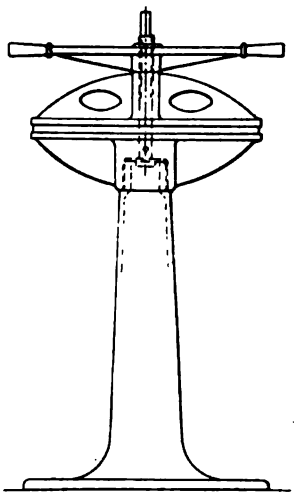


Fig. 141.—Cementing Press for Disc Grinder.

place of a belt-pulley. A useful design also is that with two discs placed facing each other, so that work may be led in between on a rest, and ground accurately for width and parallelism.

Discharge—Electric.—*See* **Induction.**

Disc Planing Machine.—A wood-planing machine, in which the cutters project from the faces of iron discs, acting upon the wood resting on a table, the outline generally resembling that of a plain emery grinder. Wheelwrights, and ship's block makers chiefly use it.

Disc Sander.—A machine, resembling the Disc Grinder in outline, having sand paper (glass paper) glued to revolving discs; it is used for trimming up and smoothing many classes of woodwork, notably boxes, and other small parts.

Disc Valve.—Applied to the circular valve of indiarubber used in condenser, and air pumps. It is secured at the centre only, with a bolt, and closes or opens by its lift the holes in a brass grid. A dished guard is attached to the bolt above, to prevent the valve from rising too high.

Disc Wheel.—One which has a solid-plated centre instead of arms. The term disc wheel is sometimes applied to a crown bevel gear.

Disengaging, Disengagement.—The devices for rapid disconnection and reconnection of rotating elements are numerous. Mainly they compose the numerous clutches, the features of which will be found described under suitable heads. Hence a clutch is sometimes termed a disengaging coupling, to distinguish it from a permanent coupling. Clasp nuts are disengaging nuts. The agents of disengagement are levers, cams, screws of quick pitch, expanding rings, wedge action in various guises. Elastic devices are sometimes employed in order to avoid shock during the act of throwing in. These take the form of springs, discs, and coils. Sometimes a connection is elastic in character, to permit of a little lateral play between the parts connected.

Dished Ends, or Cambered Ends.—These are used preferably to flat unstayed ends in many cylindrical vessels, even of large diameter, as in the shell and fire-box crowns of vertical boilers, for large steam domes, the ends of creosoting cylinders, and of air receivers for compressing plant, &c. They are not liable to cause grooving, except when of large size, and under high pressures, in which conditions flat stayed ends are to be preferred.

The strength of cambered ends is referable to that of hemispherical ends, or spherical shells thus: — In Fig. 142 (1) let:—

D = internal diameter of a spherical shell in inches.
t = its thickness in inches.
p = the internal pressure in lb. per square inch.
s = the stress in lb. per square inch; (corresponding with the ultimate tensile strength of mild steel suitable for boiler plates, which equals about 27 tons per square inch).

The strength of the spherical shell is then found thus:—The resultant of the pressures on one-half of the shell is equal to the area × pressure; or $D^2 \times \cdot7854 \times p$; which tend to rupture the shell through a plane passing through its centre. But the area of a section of such a shell through its centre is $D \times 3\cdot14159 \times t$; and multiplying this by the stress s, we get the resistance to rupture:— $3\cdot14159 \times p \times t \times s$.

These two quantities equal each other: $\cdot7854 \times D^2 \times p = 3\cdot14159 \times D \times t \times s$.

Dividing each side by ·7854 × D, we get:— $D \times p = 4 \times t \times s$; which formula is available for determining the strength of dished ends.

It can be proved that a cambered end will have the same strength as a cylindrical shell of the radius r of the curve, which equals the diameter of the cylindrical shell to which it is attached.

Take the following, Fig. 142 (2):—

Let D = 3 ft. 6 in. diameter.
t = ·035 in.,
P = 100 lb. per square inch,
S = 60,000 lb. per square inch.

Since $P \times D = 4 \times t \times S$

$$\therefore P = \frac{4 \times t \times S}{D}$$

$$\text{Also, } S = \frac{P \times D}{4 \times t}$$

$$\text{Hence, } P = \frac{4 \times \cdot 035 \text{ in.} \times 60{,}000}{42 \text{ in.}} = 200 \text{ lb.}$$

That is, the pressure P = 200 lb. per square inch. And

$$S = \frac{100 \times 42 \text{ in.}}{4 \times \cdot 035 \text{ in.}} = 30{,}000.$$

Hence S = 30,000 lb. per square inch.

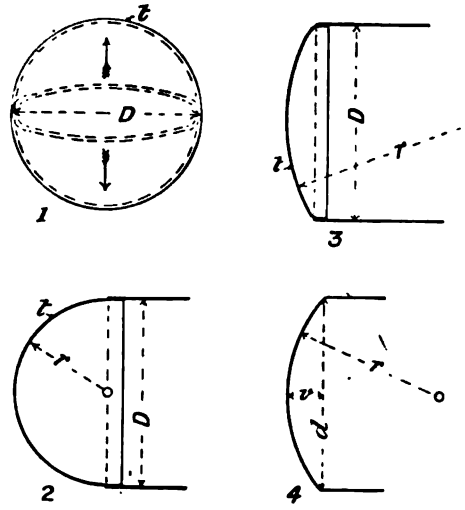


Fig. 142.—Dished Ends.

This shows that with a sphere of 42 in. diameter, a pressure of 200 lb. per square inch, a stress of 30,000 lb. per square inch exists, demonstrating that a hemispherical end will stand the same pressure and stress as a spherical shell.

It can now be demonstrated that a cambered end will have a strength equal to that of its cylinder, when the radius of the end is equal to the diameter of the shell, Fig. 142 (3).

Since radius now = diameter, D will have twice the value of the above, hence:—

$$P = \frac{4 \times \cdot 035 \text{ in.} \times 60{,}000}{84 \text{ in.}} = 100,$$

$$S = \frac{100 \times 84 \text{ in.}}{4 \times \cdot 035} = 60{,}000.$$

So that with a radius of curve equal to diameter of shell we have a pressure of 100 lb. per square inch, and a stress of 60,000 lb., or twice the stress, and half the pressure under the former conditions. This corresponds with the longitudinal strength of the cylindrical shell of a boiler of corresponding size and thickness. This follows from the fact that the strength of a cylinder to resist longitudinal rupture is twice that of resistance to transverse rupture. Transversely the cylinder section per unit length is ·7854 × 2 = 1·5708. Longitudinally it is unity × 3·1419, which is exactly twice the previous value.

To find either the radius, or the versed sine of a dished end, Fig. 142 (4):—

$$\text{The radius} = \frac{\text{versed sine}^2 + \text{semichord}^2}{2 \text{ versed sine.}}$$

In Fig. 142 (4) let r = radius,
v = versed sine,
d = chord, or diameter.

Then
$$r = \frac{v^2 + \left(\frac{d}{2}\right)^2}{2v}$$

and
$$v = r - \sqrt{\frac{4r^2 - d^2}{2}}$$

If $r = d$, then $v = \cdot 134d$, ·134 being a constant obtained mathematically.

Disintegrator.—A machine for shredding, granulating or powdering various materials, including bone, refuse, &c. The best known types comprise two grinding rings, one fixed, the other revolving. Teeth are arranged on the face of each ring, in concentric circles, spaces being left between, the teeth and the

spaces lessening in size towards the periphery. The revolving ring is driven at a speed varying between 800 and 1,000 revolutions per minute. The distance apart of the grinding rings is capable of alteration, so that the size of the product may be made coarser or finer. The stuff is fed into the centre of the machine through a hopper.

Displacement.—Specifically, the weight of a vessel in water, the fundamental law of which is:—A vessel floating at rest in water displaces a volume of water exactly equal to her own weight. The case would be the same whether the volume of water displaced were occupied by the vessel, or filled with water.

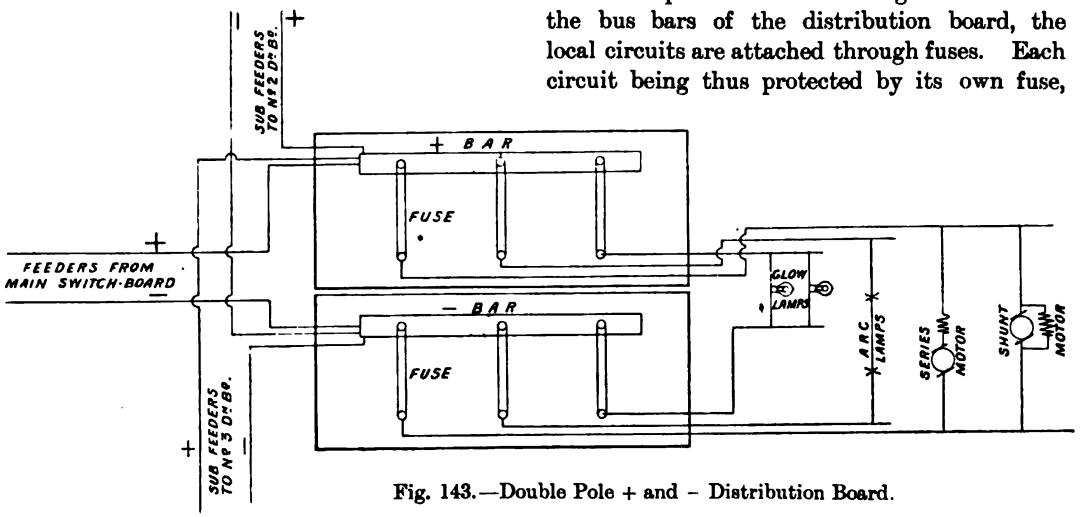


Fig. 143.—Double Pole + and − Distribution Board.

The centre of gravity of the displaced water is the centre of buoyancy.

The estimation of the displacement of a vessel is not so simple, however, as this. It is necessary to calculate it under different conditions, one being the unladen, or *light* displacement, the other when fully laden, *load* displacement. The term *mean draught* denotes the average, supposing the vessel to be on an even keel, but generally a *trim* is given to the vessel, signifying a deeper draught abaft than forward.

Distributed Load.—*See* **Beam.**

Distribution Board.—From the terminals of the dynamo, conductors of large sectional area are led away to the main Distribution Board, Fig. 143. On this are fitted the necessary measuring and recording instruments, and the main "bus bars." From these bars branches are taken, and by the closing of switches to one side of which they are attached, connections are effected with the cables supplying the various circuits in which are placed the lamps, motors, &c. These main cables or *Feeders* are extended to cover the whole field of distribution.

Wherever it is required to use the electricity, a smaller board, having bus bars and fuses, or switches as required, is fixed. The secondary distributor is usually referred to as a distribution board, the first being called the switch-board, although the function of both is the same. A pair of feeders being connected to the bus bars of the distribution board, the local circuits are attached through fuses. Each circuit being thus protected by its own fuse, any fault in itself is subject to that fuse, and the other circuits are also protected, as a fault or accidental short circuit occurring, would "blow" its own without affecting the other circuit fuses.

The main feeders may pass on to feed a second, or as many more distribution boards as required, and other pairs of feeders doing likewise in other directions, the whole output of the dynamo, collected together at the main switch-board, is in this manner distributed over any area of supply.

Dividers or **Compasses.**—These are used in all classes of metal work, and in much wood, for pitching out distances, centres, striking circles, &c. The plainest form have no means of clamp-

ing, like draughtsmen's dividers, but these are not suitable for engineers' work, owing to the risk of shifting. Various means of adjustment and clamping are shown in the illustrations. Fig. 144, A, is a wing or quadrant pattern, the compass proper, which locks securely, but does not afford means of fine adjustment; B has this feature, by riveting a strong flat spring to one leg, to press against the quadrant shoulder, the latter being prolonged into a screw, altered by means of the nut. The spring design, C, may be finely adjusted at any position of the legs. To save the tedious screwing of the nut when wishing to make considerable variations, quick-acting nuts are fitted to dividers (similarly to calipers, as mentioned in the article **Caliper**). The form may then be like D, with the screw passing through

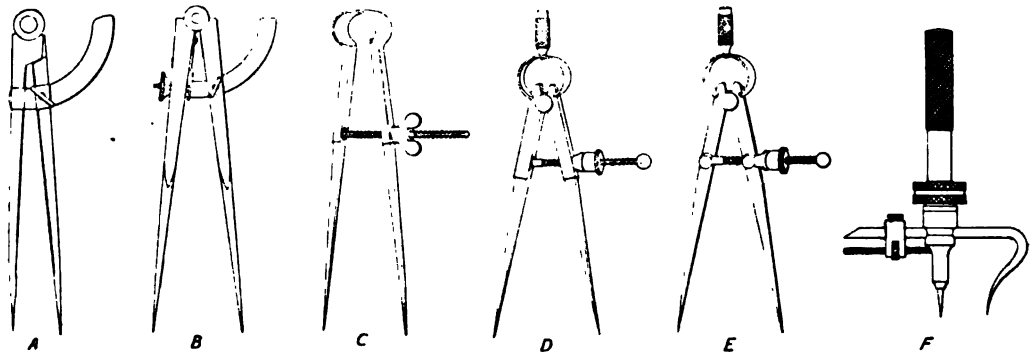


Fig. 144.—Dividers.

the legs, or like E, with thin sheet legs, having bosses for the screw. It will be noted that these tools have a small handle screwed into the top, which gives a convenient grip for striking circles, especially small ones.

Parallel dividers, F, are useful for fine work, because the points do not tend to jump out of their centres on the work, as the ordinary dividers do. A considerable range of sizes can be taken by the type F, according to the length of the bar. **Trammels** are magnified dividers, adopted when the methods of construction shown in this article cannot be applied to long spans.

Dividing Engine.—A machine for dividing a circle or a straight bar into a number of equal parts. Any gear cutting or universal milling machine is a dividing engine, but the term relates specifically to one used for marking the circles of astronomical and surveying instruments. The first dividing engine which attracted much attention was Ramsden's famous machine, accounts of which were published in 1777 and 1779. Like its successors, the leading elements were the worm (tangent screw) and large worm wheel (45 inches in diameter), with 2,160 teeth. Six turns of the tangent wheel turned the wheel one degree. The screw had a micrometer, and a ratchet wheel of sixty teeth, so that one tooth equalled one-tenth of a minute of arc. The screw could be moved an amount equal to one tooth, or several turns and parts of turns, so that the circular work attached to the dividing wheel could be graduated as required by setting the tangent screw to move the required quantities. A second engine was made for dividing straight lines.

The photo, Fig. 145, Plate X., illustrates one of the dividing engines made by Messrs T. Cooke & Sons, Ltd., the astronomical instrument makers of York. Few engineers know the great accuracy required in these machines. Messrs Cooke have frequently refused to undertake to make them because of this, the chief difficulty being the production of a large toothed wheel practically free from error, on which the success of the machine largely depends.

The machine is used for dividing circles for theodolites, telescopes, transit, and other astronomical and scientific instruments, where a great degree of accuracy is required; the lines cut have to be so fine and close together

as to necessitate the use of microscopes to see them. Usually the divisions have to be cut on silver, or metal of similar fineness, and for this purpose a fine silver steel cutter is generally employed, although a split diamond is used at times.

In the main the machine consists of a large horizontal wheel mounted on the top of a vertical axis with top and bottom bearings, carried by a frame between three pillars which rest on a concrete foundation of considerable depth. (The pillar seen in the centre of the photograph only carries the mechanism for turning the wheel and actuating the cutter. Two of the three supporting pillars mentioned are seen on each side of this, but the other is hidden by it.) Beyond the three pillars, projections of the central frame carry three vertical screws, which support a stiff gun-metal bridge with coned pin ends resting in grooved brackets raised by nuts on the screws. The bridge carries the cutter slide, which by means of the vertical screws can be raised or lowered to suit the height of work operated on. The coned pins are grooved to allow for any difference of expansion there may be between the bridge and the frame of the machine. The cutter slide can be moved along the bridge to suit the size of circle to be divided.

The large wheel is of gun-metal and of rigid form. It is 59½ in. diameter, and has 2,160 vee teeth cut in its edge. It is in the truth of this wheel and its axis and the regularity of the pitch of the teeth, that the great accuracy of a machine like this mainly lies. Not only has the wheel to be turned on an extremely true lathe, but micrometers are used for pitching the teeth cutters, and when cut any errors are reduced by a system of continuous hobbing and grinding-in of worms.

A variable-stroke crank on a floor shaft (seen on the left of the machine) gives a slow backward and forward motion to an inverted pendulum lever, from the end of which an endless cord passes on a spirally grooved drum, which is thus made to turn first in one direction and then in the other as the pendulum swings from side to side. The spindle of the drum is in line with the spindle of the worm that drives the large toothed wheel, but it only drives this in one direction, for the two spindles being separate have two adjoining discs, one carrying a pawl, the other a ratchet wheel, so that while the pawl on the disc of the spiral drum spindle drives the disc on the worm spindle in one direction when the drum spindle turns in the other direction, the pawl rides freely over the ratchet and leaves the worm spindle at rest until the drum reverses again. It is during this period of rest that the cutting operation is made to take place on the work in hand.

A pinion on the spiral drum spindle drives a train of wheels, which gives a quarter turn to two cam-discs; one of these has two cams on it and the three cams work three levers, two of which by means of rods led to the back of the machine and again forward along the bridge, give the proper motion and at the right moment to the arm which carries the cutter.

One of the cams mentioned acts on an arm which slowly turns a small ratchet wheel, and on the spindle of this is a disc with notches in it. Two pins carried on the ends of a spring lever drop into the notches if the movement of the cam has brought them into position in front of the pins; if not, their movement is hindered, and by this means one of the trains of levers and rods which lead to the cutter is so controlled, and lines of varying lengths are cut in their regular order on the work. For if a deep notch on the disc is arranged to come opposite a pin at a certain time, a longer movement is permitted to the spring arm, and a longer line is cut. By regulating the throw of the driving crank the cord motion to the driving worm is made to give from half a turn to three turns at a time to the worm, and by putting on a smaller spiral drum this can be made to give six turns at a time to the worm, and the wheel be made to move through a greater arc for coarser divisions on the work.

The machine cuts divisions from five minutes of arc up to 1 degree. By changing the notch wheels, various lengths of lines may be cut, but usually four lengths suffice for most scientific instruments.

The mechanism on the slider is arranged so that divisions may be cut on the flat, on the bevel, or on the edge of a circle.



Fig. 145.—Dividing Engine.
(Thos. Cooke & Sons, Ltd.)



Fig. 146.—Diving Bell for Dover Harbour.
(Hunter & English.)



Fig. 147.—Diving Bells Suspended from Goliaths at Dover Harbour.



Fig. 148.—Siebe-Gorman Diver's Helmet.



Fig. 149.—Siebe-Gorman Diving Outfit.

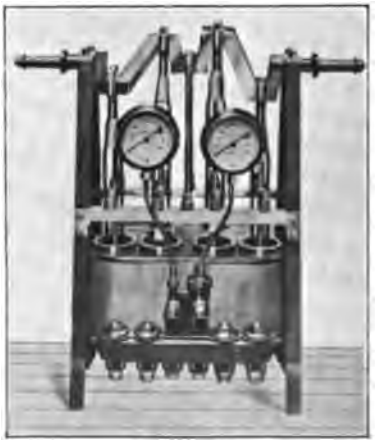


Fig. 150.—Siebe-Gorman Double-Acting Air Pumps.

To face page 140.

The machine is in a special room to keep it as free from dust as possible, and the room is kept as nearly as possible at one temperature while at work by means of heating pipes.

Dividing Head.—*See* **Index Centres.**

Diving Bell.—A vessel of rectangular shape used in submarine operations. There are two types of this machine, the air-lock, and the modern open type. The first-named is practically a portable caisson. The communication between the chamber and the shaft is by means of an air-lock and ladders.

The ordinary bell is a large chamber slung from a crane or Goliath, and ballasted and supplied with air from a compressing plant. It is fitted with seats and foot-rests for the men, with electric lamps, signalling gear and telephone. Figs. 146 and 147, Plate X., illustrate bells.

Diving Operations.—The importance of these operations has grown vastly of late years, partly by reason of the great extension of harbour construction, but largely also because of the substitution of diving dresses for the diving bell. The superiority of the former is due to the larger area over which operations can be carried on, and to the larger number of men who can be distributed. But outside of harbour work there is a vast amount of scope for divers in salvage operations, in the blasting of rocks, and removal of wrecks, in the preparations for the building of the piers of bridges, repairing of dock gates, and sluice valves, underpinning; cleaning and repairing ships' bottoms, sponge and coral fishing, &c. Besides these utilities the diver's dress is adopted for avoiding the foul air of mines, chemical works, &c.

The equipment of the individual diver includes a waterproof dress of twill or cloth fabric lined with grey or vulcanised rubber, and with or without indiarubber cuffs. A helmet, Fig. 148, Plate X., which is attached to the neck of the dress either with bolts, or with a breastplate or corselet fastening, the latter being more readily attached. The helmet receives the air supply from the pumps above. The best Siebe-Gorman helmets are of copper with gun-metal fittings, and plate glass windows protected with guards. They are fitted with a safety valve by which in case of accident enough air would be retained in the dress to enable the diver to ascend. They also have a regulating valve which gives the diver complete control over his air supply, a speaking apparatus by which divers are able to converse, Fig. 149, Plate X., a loud-sounding telephone, and an electric light are fitted. The air pumps are double-acting, Fig. 150, Plate X., the cylinders being surrounded with a cooling cistern, and are fitted with pressure gauges that denote the pressure of air and depth of water. Considerable variations are made in pumps for different conditions of working. There are various articles of underclothing, as guernseys, drawers, stockings, woollen caps. Lead weights are hung from the helmets. Leather boots are loaded with lead soles and metal toe caps, with or without corrugated bottoms, Fig. 149, Plate X. Air pipes are connected to the pumps. Dresses and adjuncts of this kind have been used on the harbour works at Douglas, Jersey, Karachi, Colombo, Folkestone, Dover, and elsewhere, and on numerous breakwaters.

The maximum depth at which divers are able to work, is generally fixed at 150 feet, or 25 fathoms. The greatest depth to which any diver has ever descended is 204 ft., or 34 fathoms. The enormous pressure which has to be sustained and the variations due to ascent and descent, set limits to the endurance of divers. At 150 feet the pressure equals 65¼ lb. per sq. inch. Messrs Siebe, Gorman, & Co., Ltd., recommend that a man of strong constitution should not ascend at a higher rate than 2 ft. per second from depths not exceeding 80 ft., and more slowly from greater depths. The reason is, that coming from a condensed atmosphere, time should be given for the muscles and tissues of the body to be relieved of the great pressure. Another precaution is not to take any food for two hours before descent so that the stomach shall not press unduly on the breathing organs.

Divining Rod.—A twig of hazel or other material, which in the hands of a "sensitive" operator indicates the presence of subterranean water. The twig moves forcibly in the hands as the location of water is approached. No satisfactory explanation is offered of the cause of the phenomena. Mr Chesterman, the expert of Bath, ascribes it to the influence of electric

currents upon the nervous system. He experiences a sudden shock, which rapidly traverses the arms, and seems to centre in his heart. The result is so exhausting that he is unable to use the wand for more than about an hour in a day. Few persons are sensitive, but some possess the qualification without being aware of it. The material used is not necessarily hazel; Mr Chesterman prefers aluminium wire bent to the V form. The depth at which water is to be found is arrived at by a formula of the operator.

When Messrs Meldrum Bros., Ltd., were erecting their new works at Timperley, they engaged the services of Mr Chesterman. He indicated three spots about 100 yards apart, where he stated there were springs capable of yielding a continuous supply of water. Two springs he estimated to be from 45 to 50 feet down, and guaranteed 250 gallons per hour from each. Wells were bored and water was found at depths of 45 and 48 feet respectively, and they are each supplying 360 gallons per hour. The third well was stated to be 95 feet down, and capable of supplying probably 1,200 gallons per hour. Water was found at 94 ft. 6 in. down, and the supply was found to be 1,200 gallons per hour. Six of Mr Chesterman's children possess the same faculty as himself. Mr Chesterman has practised it for thirty years, with but four failures.

There are other water finders in the West of England and elsewhere. The numbers of successes chronicled are far too numerous to permit of scepticism as to the genuineness of the facts of water finding by the divining rod.

Division Plate.—A plate of metal perforated with sets of holes for use on **Index Centres.** A similar plate used on lathe heads fitted for fluting, gear cutting, and similar operations that require exact divisions. A notched annular plate, with spring lever, used on gear cutting, and gear wheel moulding machines, for subdividing the full turns of the handle shaft.

Dock Caissons.—Caissons used for closing the openings of docks, being alternative to the adoption of gates. The advantages of caissons are that they may be utilised as bridges, and that they do not need the side recessed walls which gates require when swung open to allow of the passage of vessels.

The term dock caisson covers four or five groups. The term *swinging caisson* is applied to a form of single-leaf dock gate that is much wider than the gate proper (*see* **Dock Gates**), and which can be utilised as a bridge. There are only a few of these in existence.

Traversing caissons are those which are moved transversely to the opening of the dock which they close, and which, when the dock is open, have to be accommodated in a recess in a side wall adjacent, the recess being of course at right angles to the axis of the opening. Of these there are three classes, *sliding*, *rolling*, and *floating*, the terms denoting the methods by which the caissons are traversed. The features they have in common are the boxed form of construction with watertight compartments, and decks; and ballast in the bottom to keep them upright.

Sliding caissons have keels, and fenders, by which they are moved and guided along the floors of their chambers or berths. The friction is partly diminished by flotation adjustment. To avoid this is the object of setting caissons on rollers, but there is the risk of the rollers getting out of order. *Floating caissons* have no guides or rollers. They are of the *box* type, like the previous kinds noticed; or they are of the *ship* type, so called from the general resemblance of their outlines to those of a vessel. Otherwise they fit in grooves like the sliding and rolling types.

There is a good deal of machinery in dock caissons, comprising engines, boiler, and pumps, &c. Decks, watertight bulkheads, joints, questions of stability, methods of operation, and variations in details render their design and construction matters of much interest.

Dock Crane.—A type of heavy crane employed chiefly for service at graving docks; the capacity varies from 25 to 200 tons. The smaller sizes are of the portable type, whilst the larger ones are fixed; the radius is frequently considerable, and in many cases variable. The framework of dock cranes has developed on several lines. They include the Bridge, the Derrick, the Fairbairn, the Hammer,

and others, descriptions of which are given in these volumes.

Dock Gates.—Hinged gates used for opening and closing the entrances to docks. They are constructed of wood and iron, or steel.

The timbers commonly used are greenheart, oak, pitch pine, Memel, and pine creosoted. Gates made of these all weigh heavier than those of iron or steel. This is partly due to the quantity of metal fittings necessary, partly to the fact that the timbers are solid, while metal gates are built up of plates and rolled sections, and often also in watertight compartments. The advantage of the latter arrangement is that the flotation of the gates is made to partly counterbalance their dead weight, and so to reduce the power required to operate them. On the other hand, timber, especially greenheart, is cheaper and much more durable than iron. Timber endures shocks better than iron by reason of its mass and elasticity, while iron plates, like those of vessels are very liable to suffer injury.

Gates are mostly made with two leaves meeting, not in a straight line, but at an angle, the apex pointing towards the dock basin. The gates are hinged at the vertical members, termed *heel posts*, and they meet at the vertical *mitre posts*. These are essential elements in any gates. But there are two classes of gates; those in which the main girders are all arranged vertically, and those in which all except the posts first named are horizontal. In the first, the horizontal members at the sill and at the top are connected with verticals. In the second, horizontals are carried between the heel and mitre posts. Or, in wide gates, vertical *middle heads* are inserted in addition.

Figs. 151 and 152, Plate XI., show two pairs of gates, outer, and half-tide, of non-buoyant type. Fig. 151 shows the gates from the inside of the dock, and Fig. 152 shows the outer faces, with the sluices, and their actuating cylinders. The photo was taken in the course of erection, before the workmen's stagings were removed. The heels, sills, and mitre post are of greenheart. The opening and closing are performed electrically.

Docks.—Embrace an extensive department of civil and mechanical engineering. The design and construction of the docks belongs to the first branch, their equipment to the second.

Docks are of three kinds, wet, dry, and floating. The first are for the reception of vessels, irrespective of tides; the second, those in which vessels are floated, but emptied subsequently, to leave vessels dry-docked for repairs to their hulls. Floating docks are those by which vessels are raised above the water for repairs.

The development of docks, and the rapid increase in their extent, has been accelerated by the growth of liners, and tramp steamers, which render necessary immensely larger areas and draughts than were available a generation since.

The design of docks involves many problems, as shape in plan, the proportion of quay space, the walls and piers, the grouping of docks for various commodities, gates and their methods of operation, besides bridges, sheds, cranes, dredgers, &c.

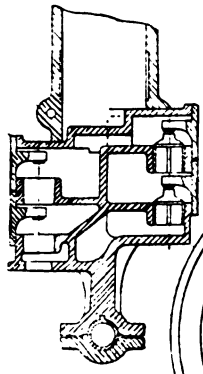
The construction of docks involves the problems of retaining walls, with a knowledge of the most suitable kinds of natural foundations. Or if these are not present, then the subject of artificial foundations has to be considered, and these embrace piling, or foundation cylinders, of iron, or concrete. The whole subject of concrete work is involved in dock construction, bag work, blocks, and monolithic work. The entrances to docks have to be regarded from the point of view of a sheltered situation, and often facility for opening and closing at all states of the tide, since the detention of big vessels idly for a tide runs up expenses. These include the entrance by one pair of ebb gates, which can only be available at high water, and a little before and after, and which in case of accident to them might result in damage to any vessels within, and stop the working of the dock. A lock combined with two pairs of ebb gates is a far better arrangement. Half-tide basins are magnified locks. The dock gates are closed at about high water, but the half-tide basins are left open as long as water enough remains over the sill for vessels to enter.

Outside of the docks are the protective and guiding works, known as piers, moles, jetties, wharves, and breakwaters. Each, the last excepted, are terms used rather loosely to

designate continuous wall-like structures extending from the docks seawards, and are in this respect distinguished from breakwaters, which are outlying works used for protective purposes only. In these the same materials and methods of construction recur, namely, piles, or concrete in various forms.

The equipment of docks comprises bridges of various kinds, as pontoon, swinging, and bascule bridges, and rolling or traversing bridges. It also includes floating, and wharf cranes, and coal tips, with the power installations necessary to operate them. This is generally an hydraulic, or electric one. Most of the subjects mentioned here are dealt with in these volumes under specific heads.

Dog.—The term is a common one. It denotes the pawl of a ratchet wheel, and the latter is termed a dog wheel. It is the loose catch which fits between collars on a sliding shaft to retain it endwise when different sets of wheels have to be engaged. It signifies the two-pronged staple used by pattern-makers for the temporary union of work, and as when making glued joints. A common nail spike is sometimes termed a dog. The jaws of jaw chucks are termed dogs, and the chucks, dog chucks. The lathe carrier which grips work between centres and is rotated by the carrier is a dog. A dog tail trowel is one with a curved handle. A dog wrench is a spanner with a curved handle, like the handle of a crane winch. For dog-shore *see* **Launching.**



Dolly.—*See* **Boilermaker's Dolly.**

Dolomite.—A material of much historic as well as present interest, as being the basic agent by which good Bessemer steel could be made from phosphoric ores. *See* **Bessemer Steel.** It is prepared as follows:—

Dolomite is a pure magnesian limestone which does not contain more than 2 per cent. of silica. Its preparation involves breaking the stone into lumps, and burning them in a kiln, or preferably in a cupola with blast, the limestone alternating with layers of coke, and maintained at a regular temperature. From 140 to 150 lb. of coke are used per ton of stone. It is then *shrunk* dolomite, and this shrinking is necessary because it contracts about 50 per cent. on heating to whiteness, and this must be done before it can be used in the converters. When shrunk, it soon absorbs moisture, and deteriorates, so that it has to be used without much delay, and stored in a dry place. It is ground finely in a pug mill, and mixed with hot boiled tar in sufficient quantity to serve as a binding material. The dolomite linings are rammed round a core, or are made into bricks.

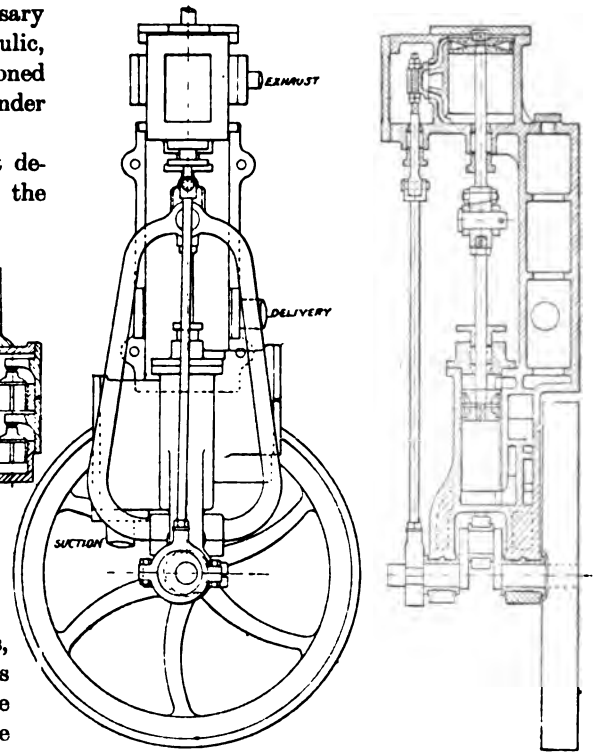


Fig. 153.—Donkey Pump.

Dome.—*See* **Steam Dome.**

Donkey.—A prefix which denotes a small auxiliary engine, or pump used in marine and land services for boiler filling. It signifies no size in particular. A small engine alone is often termed a donkey, but in general an engine and pump in combination are understood, and either single or double acting. An illustration

is given in Fig. 153, one of a series by Messrs A. G. Mumford, Ltd., the example being double acting. The pump is designed for wide utilities. The steam and exhaust suction and delivery flanges are arranged for the connections to be made on either side of the pump, as more convenient. The suction and delivery valves are interchangeable, to be fixed on either side of the pump. The foot of the pump can be bolted to a boiler, or wall, or side of a vessel. The ram is of gun-metal. The bow connecting rod, or banjo frame, is a feature common to these small pumps, economising space by comparison with that required by the ordinary connecting rod.

Doors — Watertight. — *See* **Bulkhead Doors.**

Double.—As a prefix the term has numerous applications; as double acting, double barrel pumps, and so on, some specific headings of which are given below.

Double Acting.—In a general way signifies equal action or pressure on both sides of a moving piston alternately. Hence the term is applied to engines and pumps.

Double Armed Pulley.—A belt pulley with two sets of arms. All pulleys the width of which approaches or exceeds the diameter have two sets of arms.

Double Beat Valve, or **Cornish Valve.**—A valve, which variously made, comprises essentially the design of a double faced annular valve, fitting on two annular seatings of slightly different diameters; so that the valve is nearly in equilibrium, and requires little power to lift it. An equal area of opening is obtained for an amount of lift equal to one-half only that of a single lift valve having the same diameter. In a double beat valve, the steam presses on an area equal to the *difference* between the areas of the two faces.

Double Belting.—Belting formed by cementing and sewing together two thicknesses of leather. It is used for heavy drives, being capable of transmitting nearly twice the power of single belts. *See* article **Belting.**

Double Butt Straps.—*See* **Riveting.**

Double Carbon Arc Lamp.—An open-type arc lamp having two pairs of carbons. A magnetic device is arranged in the lamp in such a manner that when one pair of carbons is consumed the second pair is put into circuit. Thus an eight-hour lamp is arranged to burn for sixteen hours with one trimming.

These lamps are often used in street lighting in cases where they are required to burn all night to daylight. *See* **Arc Lamps.**

Double Card.—An indicator card taken from both ends of an engine cylinder.

Double Contraction.—Two allowances for the shrinkage of castings, which have to be made on patterns from which patterns of metal have to be prepared.

Double Curve Teeth.—Cycloidal teeth, as distinguished from involute teeth of single curve. *See* **Gears.**

Double Cut.—*See* **Files.**

Double Driver.—A lathe driver with two prongs, of which the Clements' is the original design. *See* **Driver,** and also **Carrier.**

Double-Ended Boiler.—A marine boiler fired from both ends. The design is substantially that of two single-fired boilers placed back to back, with the back plates omitted, the return tubes coming into a common combustion chamber. But modifications in these arrangements occur. Instead of one large combustion chamber common to all the furnaces, furnaces in line may have one chamber common to the two furnaces only, with water spaces dividing them. In this design the bursting of a tube would not throw the whole boiler out of action. In another design the whole of the furnaces at one end have a common combustion chamber, and those at the other end another chamber.

Double Gear.—The use of two pinions and two wheels in combination. It is applied in the driving of lathes (*see* **Back Gear**), of drilling and other machine tools, and to most kinds of crabs and cranes. The term involves no relation to the amount of the mechanical gain, since that is a question of relative diameters, but only to the employment of the combination named above.

Double-Headed Rail.—A railway rail having both heads alike, the original idea being that the rail could be turned over to wear both heads out.

Double Helical Gear.— *See* **Helical Gears.**

Double Pole Switch.—Switches are often linked together in pairs so as to disconnect both positive and negative currents at the same time, thus rendering both cables "Dead," when they may be handled with safety.

On 3-wire systems, three single pole switches are linked and used as a 3-pole switch.

Double-Ported Slide-Valve. — A valve which is pierced with two sets of ports and passages for the admission and exhausting of the steam. The length of stroke is only half that of a slide-valve having single ports, being equal in length to the sum of the double ports. The arrangement of ports is such, the cylinder being also double ported, that a larger area is opened to exhaust than to steam, hence the term *exhaust-relief*, and *equilibrium* applied to these.

Double Riveting.—*See* **Riveting.**

Doubles.—*See* **Tin.**

Double Shaper.—*See* **Shaping Machines.**

Double Shear.—Signifies a riveted joint having double fish or covering plates, which equalise the shearing strain on the rivets.

Double Shear Steel.—*See* **Shear Steel.**

Double-threaded Screw.—Two screws of equal pitch formed round the same body at distances apart equal to half the pitch of each screw. The true pitch, therefore, is twice that of the apparent pitch. Such screws owe their value to the quick pitch, with resulting rapid rate of traverse. For the method of cutting them, *see* **Screw Cutting.**

Dovetailing Machines.— Machines for cutting the dovetails in the ends of boxes. They are used in making cartridge boxes, and the better class of boxes and packing cases generally. The oldest type is the Armstrong, in which circular saws set diagonally to the proper angle remove the material from the board clamped on a table, which is traversed past them. A more recent machine is Hunting's patent, shown by the drawings, Figs. 154 and 155.

This machine is automatic in all its movements, and cuts dovetails in two adjacent pieces at one operation by means of one cutter. The two pieces of timber are securely held by screw cramps whilst being operated upon, one piece being held horizontally by the cramps A, the other vertically by the cramps B. The cutter is secured by an arrangement which permits of giving it a little eccentricity so as to cut tight or slack dovetails. The cutter spindle C and feed mechanism are driven from a countershaft D at the back of machine.

After fixing the cutter and timber, the machine is set in motion, and by means of suitable gearing and two disc cranks E and F (at right angles to each other) longitudinal and cross traverse motions are obtained simultaneously. The disc crank E causes the table, with the timber screwed thereto, to be continually moving to and fro, and at each reciprocation a dovetail is cut into each piece of timber. The disc crank F develops a to-and-fro motion longitudinally on the small slide G. A ratchet is fitted to this slide, by means of which the table is made to move in one direction only; *i.e.*, to the left. The longitudinal and cross traverse motions are timed to work together.

The disc crank F may be adjusted to give different pitches to the dovetails, and the disc crank E can be adjusted for different depths, and the shape and size of dovetail may be altered by simply changing the cutter.

Dovetails.—The chief interest of these appeals to the pattern-maker, who employs them less for framing permanent patterns than for the temporary attachment of loose pieces, or in special forms, for purposes of junction.

Dovetails are more reliable than skewers for holding loose pieces during ramming; they are therefore preferred in high-class patterns. Pieces skewered on run risk of being set wrongly, or sometimes of being omitted and lost. But such cannot happen with pieces fitted by dovetails, since they can only fit one way, and the dovetailing is apparent.

In some permanent work special forms of the dovetail are useful. In pipe work especially it is the best method of fitting bends to straight lengths. In some brass-finishers' work it is used with advantage, avoiding the insertion of screws and nails which permit of shifting of the parts.

Dowells, or Dowels.—Pins used by pattern-

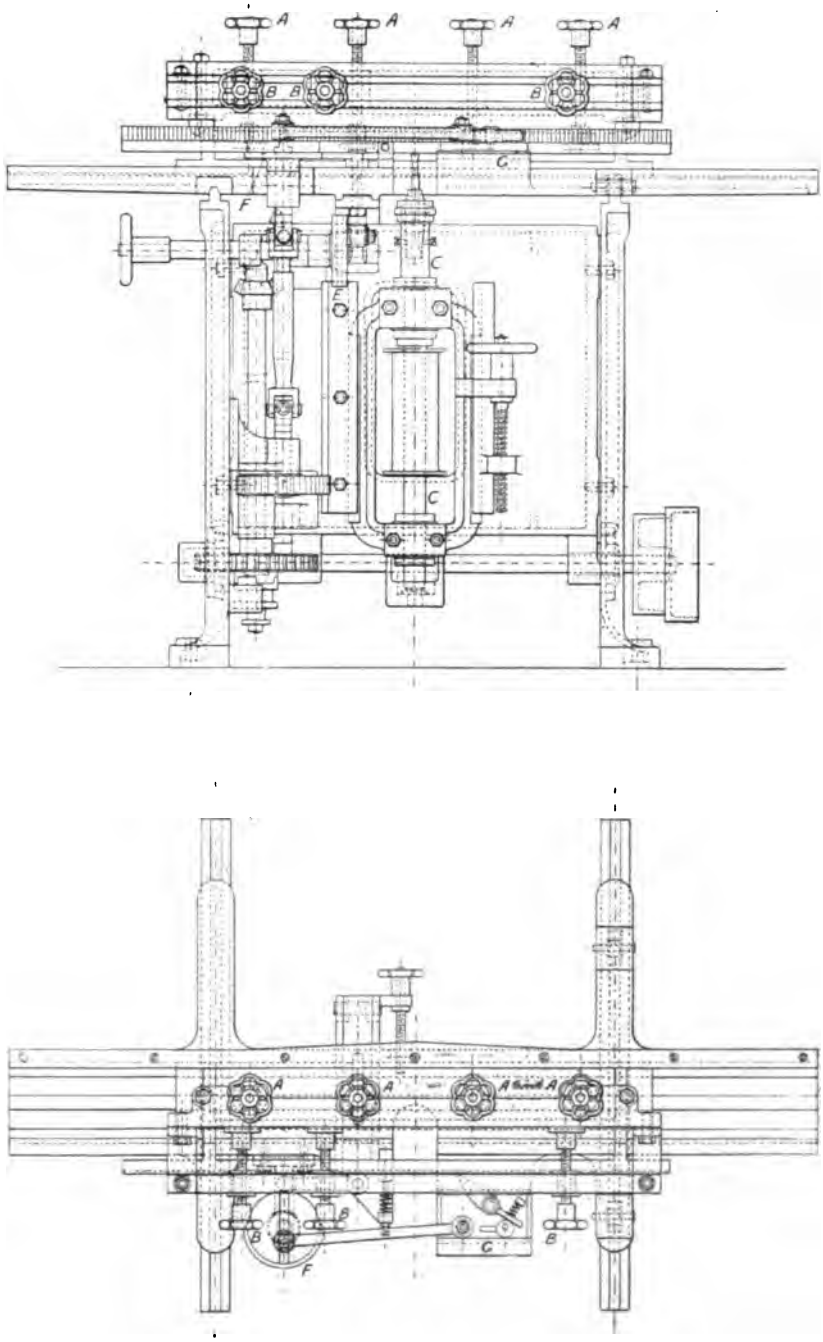


Fig. 154.—Dovetailing Machine. Front Elevation and Plan. (W. B. Haigh & Co., Ltd.)

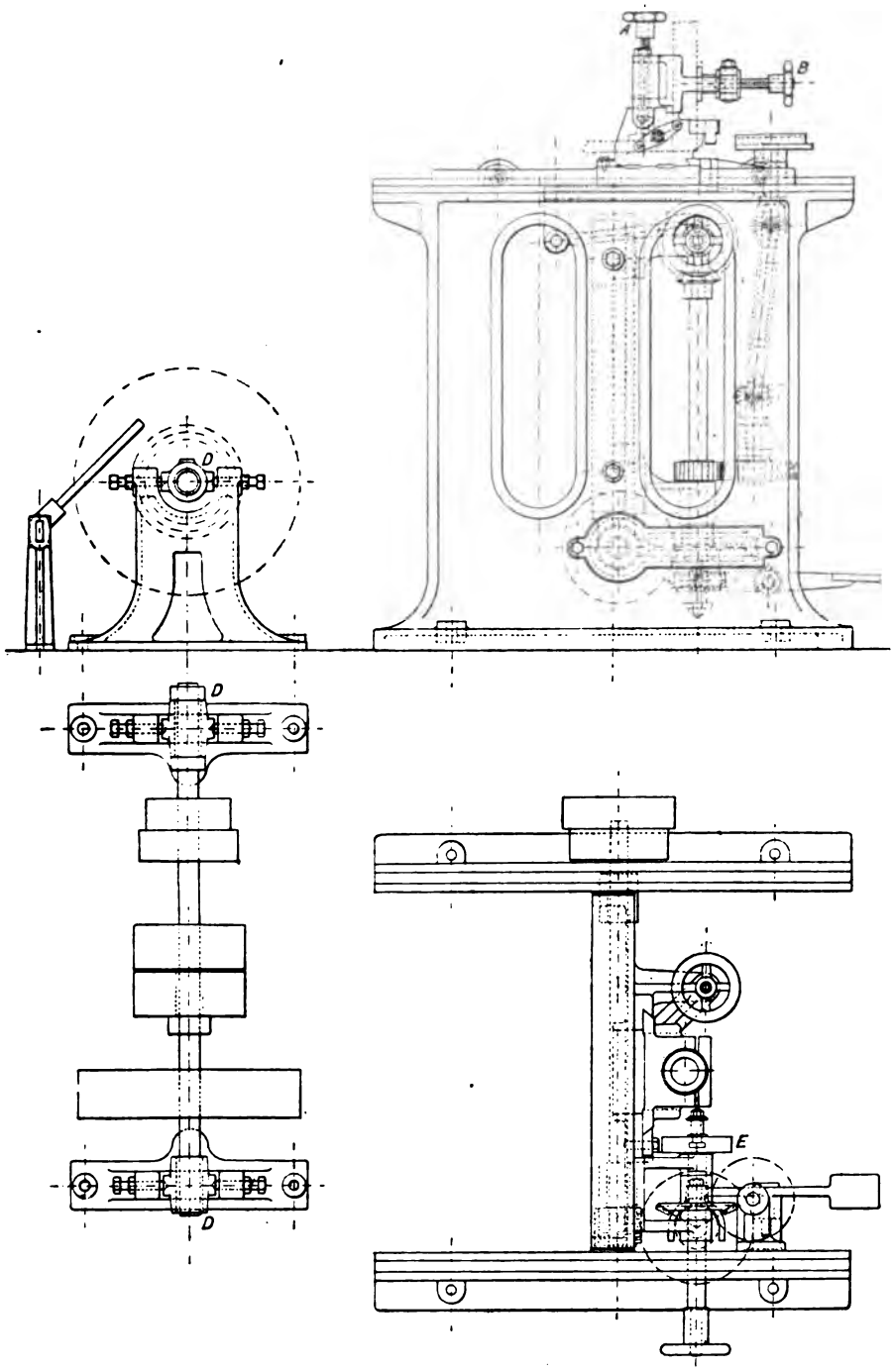


Fig. 155.—Dovetailing Machine. End View, Countershaft, and Part Plan.

makers for fixing the position of loose parts that have a vertical lift, or one perpendicular to the plane of the joint. The dowell fits tightly in one portion of the pattern, and loosely in the other, so that it remains permanently in one of them. The dowell may be nearly parallel save for the slight taper in the loosely fitting portion, or it may be fitted with a smaller stem and shoulder.

The locations of dowell holes are marked by squaring and gauging across from the edges of the pieces, or by laying a common pin on the intended centre, and pressing the two pieces together, so leaving the impression of the head in both, or by boring holes through one piece into the other.

For permanent work metal dowells are used, either the plain peg and cup, or the plate form. The first is suitable for small patterns, the second for those of medium and large dimensions. Peg and cup dowells are centred by the methods already noted for wood. Plated dowells are fitted by sinking one portion, that containing the dowell hole, into its pattern part, and then dropping the other or dowell plate on it. Then the top portion of the pattern being lowered upon this, the marks of the nibs will be guides for letting it into its place.

In dowelled symmetrical halves of a pattern, there is no risk of the moulder turning them the wrong way about. But there is such risk in the case of many merely loose pieces. This can be avoided sometimes by putting one dowell only in the centre, as in the case of a circular boss. Or by putting two dowells so located that turning the pieces about the wrong way would be quite apparent, or by cutting crosses, or stamping letters or figures at one end to indicate the proper position.

Dowson Gas.—*See* **Gas Producer.**

Draft.—*See* **Taper.**

Draft Tube, or **Suction Tube.**—A tube placed below a reaction or drowned turbine in cases where it is desirable that the wheel shall be placed at a considerable height above the level of the tail water, as when it may be desirable to render the wheel readily accessible, and to shorten the main shaft. The tube is essential when the turbine is fixed above the level of the tail water, because in the drowned type the water must fill the buckets without access of air. The condition for its employment is that of a good head of water. Its length is usually limited to less than 10 feet, and seldom exceeds 5 feet. Its lower end must come 3 in. or 4 in. below the level of the water in the tail race. It is generally parallel, but is better if enlarged towards the lower end.

Drag.—The bottom part of a moulding box. Drag links are the rods by which the slot links of valve gears are moved over for forward or backward gear. A drag rope is that by which logs are drawn up to a circular saw. A drag plate is the platform or main footplate of a locomotive engine behind the fire-box.

Drainage.—*See* **Sewage.**

Draught.—The **Taper** of patterns. The volume of air which passes through a furnace in a given time, the result of the production of a partial vacuum in a chimney. Draught is natural, or induced, or forced. *See* **Chimney, Forced Draught. Induced Draught.** The term draught, also denotes the difference in area of a rolled bar between one pass and the next.

Drawback.—The drawback of the iron moulder corresponds in function with the false core of the brass-founder. It is an alternative to the adoption of cores, or of loose pieces. It is used in green, and in dry sand; in work bedded in, and turned over, though mostly in the former. The body of sand may not be actually drawn back laterally, though the term would seem to signify that. It is as often lifted vertically after the withdrawal of the main body of the pattern.

A drawback is a mass of sand carried on a plate, or a grid. A joint must be made between the plate and its sand, and the portion of the mould against which it fits, because there is no other guide by which to return it into its place. Hence, too, the joints must generally be sloped to permit of separation, and closing without damage to the sand. Provision must be made for lifting the plate and its sand, usually with eyes cast in, and coming up close to the top of the cod of sand. The judicious employment of drawbacks will often prevent the necessity for turning a mould

over, or for using a three-part instead of a two-part box.

Draw Bars. — The coupling rods of railway rolling stock.

Draw Bench.—A bench on which tubes are drawn. One of these is illustrated in Fig. 156; by Samuel Platt, Ltd., to which the following description refers.

The tubes, which have previously been drawn down on breaking down benches from the hollow blooms, and have also been subjected to the process of swaging or tagging in a reducing machine, are slipped over the bulb of the plug mandrel, than which they are slightly larger in internal diameter. The mandrel, with the tube on, is then placed in position, and the tagged end of the tube projecting through the drawing die, is caught by the wagon grips, and the tube is thus drawn, lubricant being applied as required.

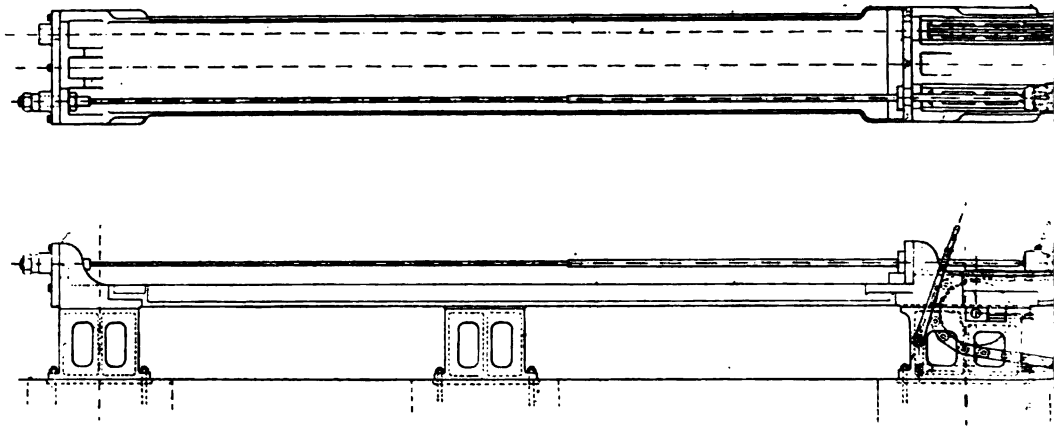


Fig. 156.—

The connector to which the end of the mandrel is attached to the mandrel plate has nuts, which are set so far apart that they allow the mandrel head to be pushed back some little distance from the die-plate, when after removing the die the tube may be easily threaded upon the mandrel.

The dies are hardened discs of steel accurately finished in the bore, and in section they have convex edges.

When the drawing process is effected on a solid mandrel, the tube, which is tagged as in the previous method, is tightened on to the mandrel by the act of drawing, and has to be removed by means of a reeling machine. In this process no mandrel end to the draw bench is necessary, as supports of any kind may be used to rest the tubes containing the mandrels on.

Draw benches without mandrel ends are also extensively used for the bright drawing of bars of steel and many other metals. The method of operation is very similar, the bars themselves being tagged.

Draw Filing, or **Poker Filing.**—Smoothing metal work by the movement of a smooth file held nearly at right angles with the direction of traverse. It removes the marks of previous filing preliminary to the application of emery cloth.

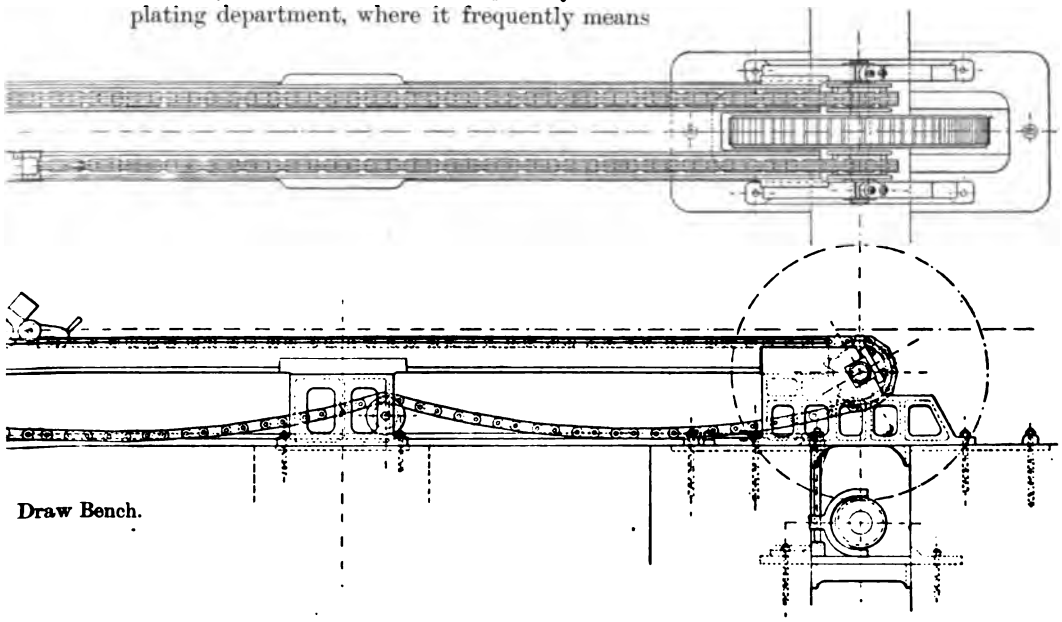
Draw Hook.—The central hook of a railway vehicle at the end of the draw bar.

Draw-in Chuck.—A type of spring chuck fitted to lathe and screw machine spindles, which closes upon the work when drawn backwards, through the medium of a coned nose. Examples will be noted in Fig. 173, Vol. I., and Figs. 135, 136, and 141, Vol. II.; the push-out chuck acts, as its name implies, in the opposite direction (see Fig. 167, Vol. I., and Fig. 113, Vol. III.). The draw-in principle is also applied to milling machine spindles.

Drawing.—Used as a prefix to many terms. Drawing down signifies the reduction of forged work by a process of fullering, and hammering. A cutting tool is said to draw-in when it has so

much top rake that it is pulled in towards its work, with resulting hitch. Castings are drawn when the metal is too strong, or insufficiently fed, with resulting hollow spaces, or depressed areas, or spongy and open grain. To draw a furnace fire is to rake it out. The drawing of patterns signifies their delivery from the mould. To draw temper is to remove hardness from steel by heating, and cooling down slowly. Drawing-on is pulling wheels over their axles.

Drawing Board.—A board employed for drawing upon. When used in the shops it is generally of large dimensions, especially in the plating department, where it frequently means the floor of a room or loft where work is marked out full size.



Draw Bench.

In the drawing office there are several sizes in vogue, the most usual being suitable for double-elephant paper; the most satisfactory are those made from well-seasoned best selected pitch pine free from knots, shakes, or other defects. They are built of several pieces of timber, having saw cuts in the longitudinal sense, and fitted with a batten at each end. These battens have slotted holes for the screws, in order to permit expansion and contraction without warping of the board. A thin strip of ebony is laid down the working edge of the board for the tee square to rub against. Ordinary drawing boards are used either upon a sloping desk, or are packed up at the back to give a slight slope for working.

Drawing Dies.—When sheet-metal articles have to be formed into cup shapes, drawing is the process adopted, the principle being that of forcing the sheet down with a plunger into or through a die.

When drawing is done on thick metal, as in the cartridge case work shown in Fig. 123, Vol. III., the die is a simple one, with an aperture. In working thin sheet, however, this is not sufficient, since the metal would buckle or pucker all around when the plunger descends. The device shown here in Fig. 157, A, must therefore be employed. A pressing die or holder, *a*, descends on the blank (shown in black) holding it with sufficient pressure upon the top face of the die *b*. The plunger, *c*, then descends through *a*, and draws the metal into the shape seen alongside. The ejector seen in *b* subsequently rises, and lifts the piece out of *b*. The depth and diameter of these dies are varied of course to suit the work. In very deep drawing, two or more operations are done in successive stages, the piece being cupped in one die, placed

in another, fitted with a blankholder which presses on an angle at the bottom corner of the cup, and holds it frictionally while the further extension is done by the plunger.

Double-action dies are those which blank and draw in one operation. B shows a set for a plain cup shape. The blanking die descends upon the sheet which rests on *b*, and cuts a circle by the sharp edge on top of *b*; *c* then comes down and pushes the cut disc through the hole in *b*, whence it drops to the floor. If the bottom of the article has to be made otherwise than plain, the style of dies in C is employed, the bottom die and the plunger being formed suitably. As the piece cannot then be pushed right through, an ejector rod, as seen, must be raised through the bottom die. Combination dies is a term applied also to these double-action types, but it should be more properly restricted to the style employed only for shallow work, such as tin covers, used in a single-acting press; the blanking punch is formed in one with the drawing punch, the action being only that of cutting a blank, and turning down shallow edges. Triple-action dies are frequently used instead of the double-action type in C, to abolish the upward ejection of the cup, which keeps the operator waiting before another piece can be produced. In the die, D, the blanking is done with *a*, followed by the plunger *b*, but instead of pressing into the bottom of *c*, the article is carried down to the plunger *d*, which shapes, or embosses, or letters the bottom by pressure against *b*. The latter rises, carrying the cup with it, until the ring *e* (sprung into *c*) is met, when it trips the cup off and lets it drop down, and through a hole in the base, *f*. The press table being on an incline, the object slides out to the ground.

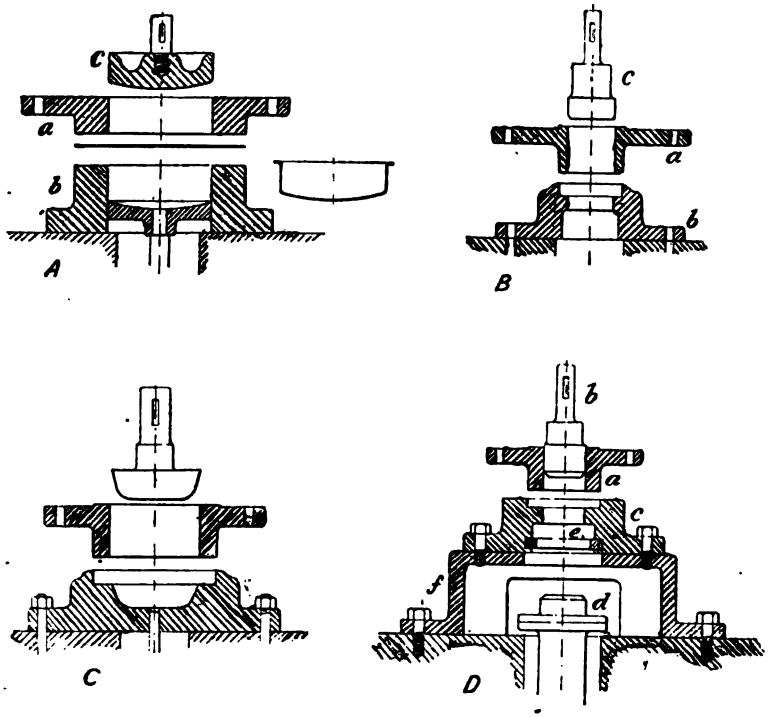


Fig. 157.—Drawing Dies.

Drawing Instruments.—The tools of the draughtsman, usually comprising a set of large compasses with lengthening bar, and pen and pencil points, pen-bow compasses, pencil-bow compasses, drawing pens, dividers, set of spring bows, and beam compasses. They are generally assembled in a case, together with several implements such as knife, key, protractor, &c. In addition to the above, a considerable number of instruments, special and otherwise, are in use, such as special ruling pens, proportional compasses, planimeters, &c.

Drawing Office.—The department in which drawings are produced; a well-lighted room specially furnished for the accommodation of draughtsmen and for the storage of drawings. The work done therein comprises the designing of machines and structures, the estimation of weights, preparation of working drawings, tracings, and prints, compilation of bills of

quantities, both for raw material as well as for finished parts. Like other departments the drawing office has its divisions of labour, skilled and unskilled. The best men are engineers of considerable experience and knowledge, to them is intrusted the production of new designs and working drawings for the same. Then come a class of men who can make drawings differing slightly from copies set them, but yet are not sufficiently educated or experienced to scheme fresh work; they therefore take a second place. The making of tracings is done largely by girls, and scarcely ranks as skilled labour. Photo prints are made by an office boy or other low-salaried person.

The organisation of a drawing office depends upon its size and upon the class of machinery dealt with. An average office would have 20 to 30 persons on the staff, whilst some large firms have 100, or more. In a small office the chief and his assistant are able to economically supervise and check the whole of the output; but in large offices there are definite rules laid down for the routine of the office, the method of constructing a drawing as regards lines, lettering, and description of parts and metals is standardised, arrangements are made to acquaint the draughtsmen with stock lists and standard details, a sound system of checking drawings is laid down, &c. &c.

A draughtsman as a rule leaves his drawing at the pencil stage and passes it on to be traced by cheaper labour; it is then checked through, and lists are written out for raw material required, and in some places complete detailed lists of pieces are compiled for use in the shops.

The printing room is invariably a separate apartment, but it comes under the control of the drawing office.

Drawing Paper.—Specially manufactured for the use of draughtsmen, &c. The leading sizes are as follows:—

Demy	15½ in. × 20 in.
Royal	19 „ × 24 „
Imperial	22 „ × 30 „
Atlas	26 „ × 34 „
Double Elephant	27 „ × 40 „
Antiquarian	31 „ × 53 „

Intermediate sizes are made but are not in general use; drawing papers are also made in continuous rolls up to 50 yards in length, and from 27 inches to 62 inches wide.

A very wide range of qualities are obtainable, from the cheap cartridge paper used for rough work up to the finest hand-made material.

Drawing papers are also supplied with faint rulings in squares, termed sectional papers; the rulings may be fractions of an inch, or millimetres, and tenths. Such papers are very useful for rough plotting without scale or square, or for setting down curves representing varying factors and data. The sizes of these papers do not correspond with the regular sizes of drawing papers, but vary with different manufacturers.

Drawing Press.—A machine in which **Drawing Dies** are used to cup or extend sheet-metal articles. There are two main types —the single-action and the double-action, the first having one ram only, for simple drawing, the second two, one within the other, for blanking and drawing. Eccentrics, cranks, and toggles are variously employed to impart the reciprocating motion. An automatic clutch is fitted to release the ram and let it remain at the top, until another pressing is wanted.

Fig. 158, Plate XI., shows a typical drawing press driven by belt and spur gear, operating a shaft, which actuates the central ram by a crank, and the outer ram by two cams. The relative movements of these two are of course varied to suit the dies which are used.

Drawing Table.—A drawing board combined with a table built as a complete article of furniture, the board usually being arranged to swing at various angles. The tee square is displaced by a parallel rule; the table proper is fitted with drawers for instruments. The leading feature is the capability of having the drawing board in a nearly vertical plane, with a consequent healthier attitude for the draughtsman.

Draw Knife.—A double-handled, broad, chisel-like tool pulled towards the workman. It is used for removing coarser and broader chips from the edges of boards and strips than could be cut with the ordinary chisel, and in

circumstances for which the axe would not be so convenient.

Dredger, Dredger Boat, Ladder Dredger, or **Bucket Ladder Dredger.**—Terms applied indifferently to the floating form of dredger with which submarine excavation is effected by an endless chain of buckets. These include three main types, the single, and the double ladder, and the hopper dredger. The single ladder is placed centrally, the double ladder to right and left of the centre. Each may be at the bow, or the stern—*bow well*, and *stern well* types. The hopper type includes one or more hopper compartments on board to receive the spoil, instead of discharging sideways into separate hopper barges for carrying the spoil out to sea.

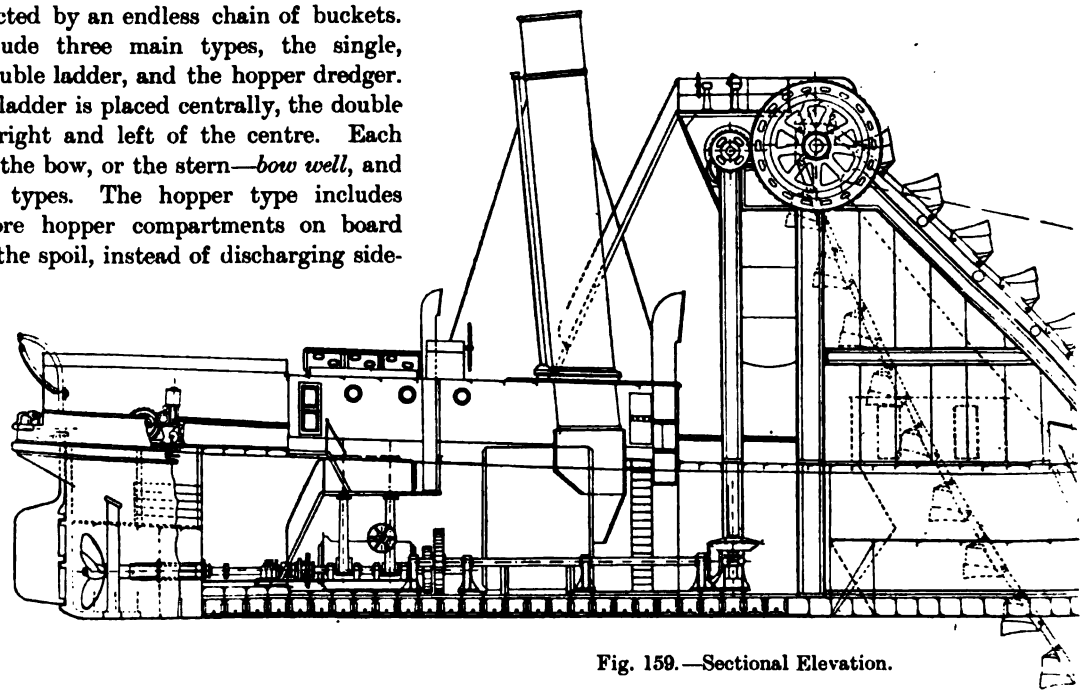


Fig. 159.—Sectional Elevation.

The illustrations, Figs. 159, 160, 161, show a 1,000 ton twin screw barge-loading dredger made by Messrs Wm. Simons & Co., Ltd., for the Bombay Port Trust. The principal dimensions are — Length between perpendiculars, 192 ft.; breadth, moulded, 36 ft.; depth, ditto, 13 ft. It dredges to 44 ft. depth of water.

Compared with other dredging appliances the work of the ladder dredger lies in smooth water in deep excavations; specially in continuous dredging, where all kinds of materials are met with, and where it is necessary to leave a level bottom. Hence the reason of the popularity of the ladder type in harbours, docks, and estuaries, since no other single type of dredger is capable of fulfilling all these conditions.

Though dredger buckets are capable of excavating hard and soft ground, gravel, broken rock, clay, sand, and mud, yet when there is a predominance of either kind, special buckets are desirable, and two sets of buckets are often provided, one for soft, the other for hard ground. For soft material their capacity is large, they have been constructed for as much as 55 cubic feet capacity. For hard ground they are smaller, and for very hard ground, ripping claws alternating with every three or four buckets have been fitted.

The ladder of buckets is the central element in the design. It consists of a number of scoops attached loosely to an endless chain, with pins. The chain is driven round tumblers, one above, one below, the upper one being the driver, receiving power from the engines through spur or bevel gears.

The top tumbler is almost invariably either four, or five-sided, the bottom one five, or six-sided. The four-sided tumbler involves the use of a hunting link in the chain to prevent uneven wearing of the tumbler. To have six sides would involve some risk of slip after a little wear, hence the number four, or five is selected.

The bottom tumbler, not being a driver, has

from five to six sides. Both are either cast in steel, or in iron, with chilled faces.

The buckets were formerly a job for the plater, being bent and riveted, and welded up, or pressed. They are occasionally cast in steel, and the lugs for the links being cast, avoid the need of riveting these on. Steel mouthpieces carrying the cutting edges are riveted to the fronts, and holes are punched to allow the water to run away. The sides of the buckets should be well tapered in both directions to facilitate the discharge of materials. Buckets are now generally built with cast steel backs, bodies of mild steel, and the cutting lips of plates of harder quality.

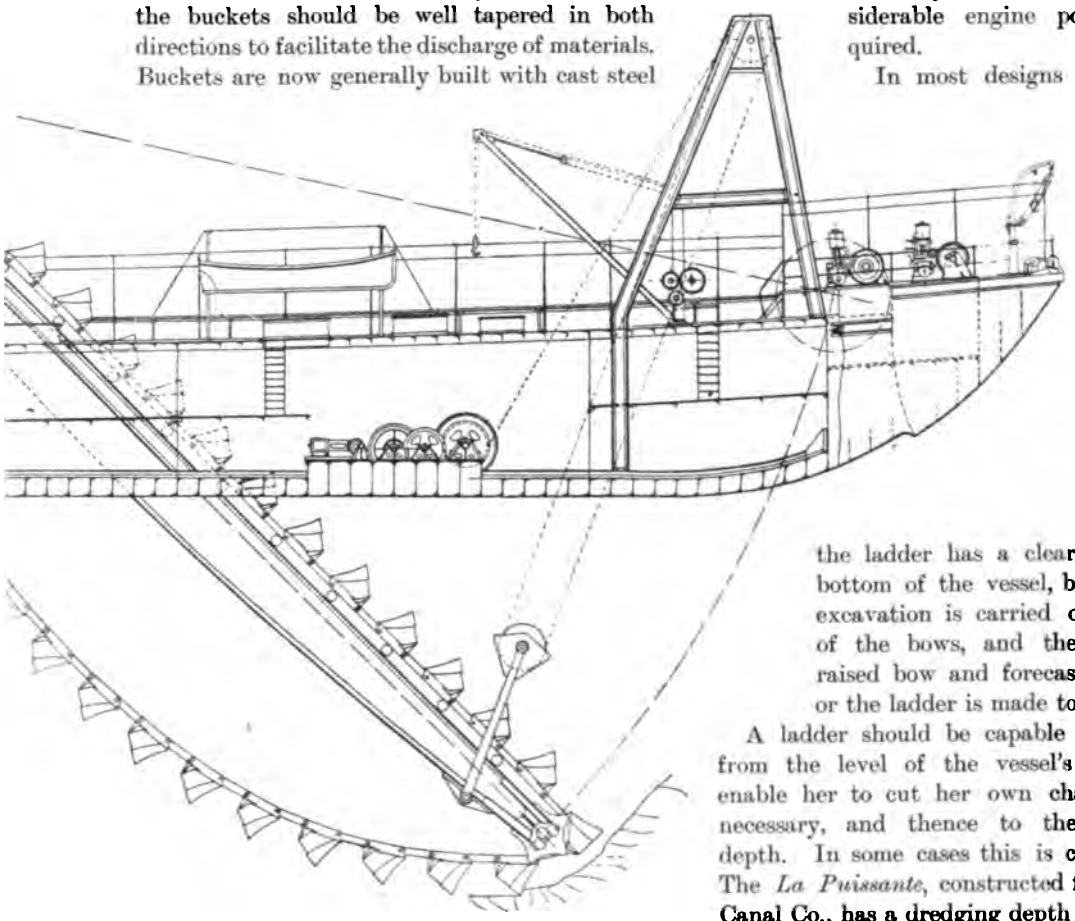


Fig. 159.—Dredger. Sectional Elevation.

The pins which connect the buckets to the links wear rapidly, lasting only from twelve to eighteen months, for the same reason that the chains and dogs of grabs wear, namely, the constant presence of gritty matters. They are therefore made in specially hard steel. They should be turned round at intervals to promote uniformity of wear.

The bottom end of the ladder is attached to the hoisting gear, which is usually independent of the main engines. The purpose of this gear is to raise the ladder clear of the bottom when steaming into position, or out at sea, and to lower it to the proper depth required for excavating. As a complete bucket ladder weighs from say 80 to 150 tons, considerable engine power is required.

In most designs the end of the ladder has a clear lift to the bottom of the vessel, but in some, excavation is carried on in front of the bows, and then either a raised bow and forecastle is built, or the ladder is made to *traverse*.

A ladder should be capable of dredging from the level of the vessel's bottom to enable her to cut her own channel when necessary, and thence to the maximum depth. In some cases this is considerable. The *La Puissante*, constructed for the Suez Canal Co., has a dredging depth of 40 feet, and the British Admiralty dredger, *St Giles*, 54 feet below water level.

Although the ladder dredger is indispensable in deepening tidal ways, harbours, and docks, its mechanical efficiency is very low. Mr I. J. Webster took a number of indicator diagrams of various dredgers, and found heavy friction losses. A large proportion of this was absorbed in merely driving the empty machinery. From

these experiments he deduced the following formulæ:—

I.H.P. = 0·04 W $\sqrt{H}$ for very stiff clay or mud.

I.H.P. = 0·034 W $\sqrt{H}$ for hard clay and indurated mud.

I.H.P. = 0·026 W $\sqrt{H}$ for soft mud and light sand.

Where H = the height of the top tumbler shaft from the surface of the ground to be dredged.

And W = the number of tons per hour to be dredged.

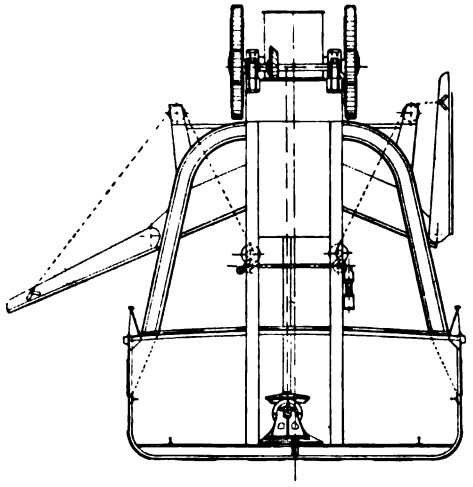


Fig. 161.—Cross Section of Dredger.

With regard to the cost of dredging, almost the only thing to be said is that no general statement is possible, because local conditions vary so much. It would be easy to give statistics of this work in different localities, but no useful rule could be deduced therefrom.

The vessels themselves are built of steel,

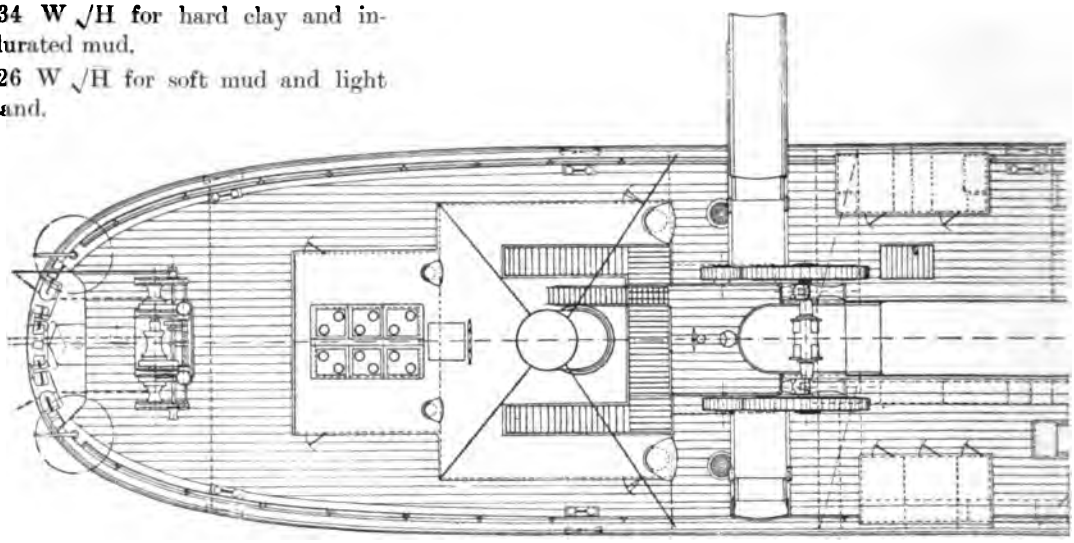


Fig. 160.—Dredger. Plan.

with watertight compartments, and transverse bulkheads. Compound, and triple expansion engines, and multitubular boilers are employed. The vessels are rated by their dredging capacity per hour, and in the case of hopper barges by their hopper capacity, and steaming powers with hopper full.

Dredging, or **Excavating**.—Terms often used interchangeably to denote the removal of material below water, or in the dry, but which are applicable to the operations of a large number of distinct mechanisms.

There are three principal groups of dredging machines, each one better suited to certain conditions than the others.

The *ladder dredgers* are utilised on vessels, and on land, and will be found treated under **Dredger**, and **Excavator**. Another group is the **Grabs**, and the third the **Sand Pumps**.

The economical importance of dredging can hardly be over-estimated. It is required in the maintenance as well as in the construction of harbours, docks, canals, and in the deepening of navigable rivers. It is adopted for preparing ground, for deepening channels, for excavating new canals, and channels, and also for removing deposits that accumulate in some

tidal ways. An alternative sometimes exists in the training works by which the natural scour of a swift river or a tidal stream can be made to excavate or to maintain a channel, but the cases are few in number by comparison with those in which dredging must be done.

Some of the great shipping centres of the

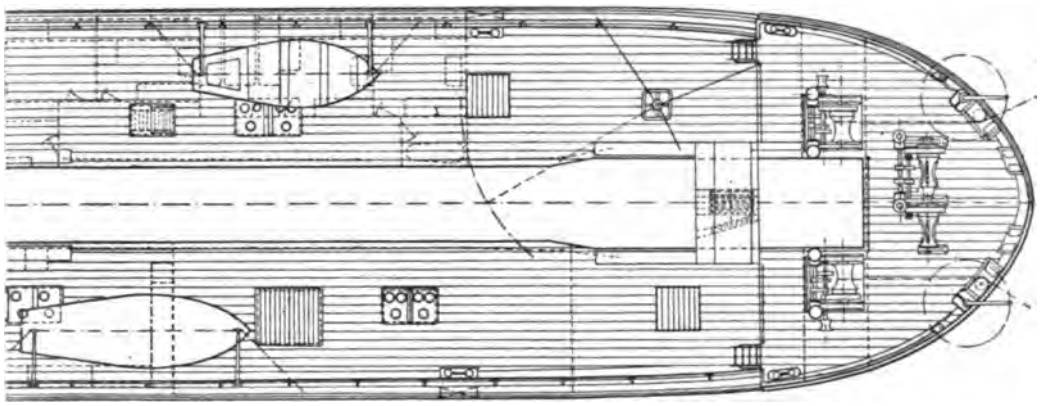


Fig. 160.—Plan.

country owe their existence to the constant persistence in dredging operations: the Clyde, the Tyne, the Mersey for example. The advent of the mammoth liners has brought dredging into greater importance, in consequence of the necessity for deeper channels at the ports of call, to accommodate the vessels of great draught. In Britain, New York, the South African ports, the Suez Canal, and in the East the dredger is always in evidence.

No single machine is suitable for all duty; the functions of each will be found discussed under the heads previously referred to.

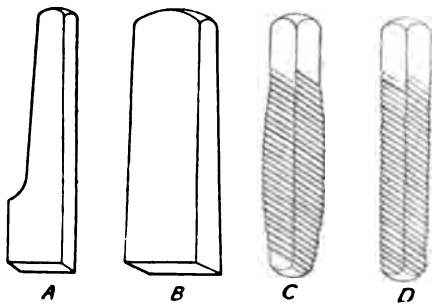


Fig. 162.—Drifts.

Drift, Drifting.—This operation, called broaching in America, signifies the cutting out of holes by forcing in a steel drift, a preliminary round hole having been first drilled to get out the bulk of the metal. It is done both by hammer, and by machine. The drifts are either smooth, Fig. 162, A, and B, with bottom cutting edges, or serrated, C, and D, with more rapid effect, and power of guidance. They are made in other shapes besides square and oblong; their principal use is for comparatively small holes, such as those in spanners, handles, &c. A lubricant is applied when working on wrought iron and steel. The machines employed for forcing are either hydraulic, or rack driven, forcing the drift downwards, while the work rests on a bed, the hole in which permits of the drift passing down.

Drifting also signifies the drawing into line of plated work, by driving a tapered or bellied smooth drift into the rivet holes until they come flush. It should only be practised in moderation, to avoid injurious strains.

Drill.—Used in most classes of metal working for originating holes, and enlarging ones cast or forged. The feature in all consists of two or more cutting lips, combined with a body which may or may not afford guidance. The most accurate results are obtained by the former type, of which the fluted and the twist drills are representative. For a good deal of work, however, the drill without a circular guiding shank is sufficiently accurate, especially as broaching or reamering often follows.

The ordinary flat drill, Fig. 163, A, is used more than any other type, the twist excepted;

it cuts freely in brass and cast iron, but not so effectively in wrought iron and steel. The cutting angle, *a*, varies between 5° and 6° for

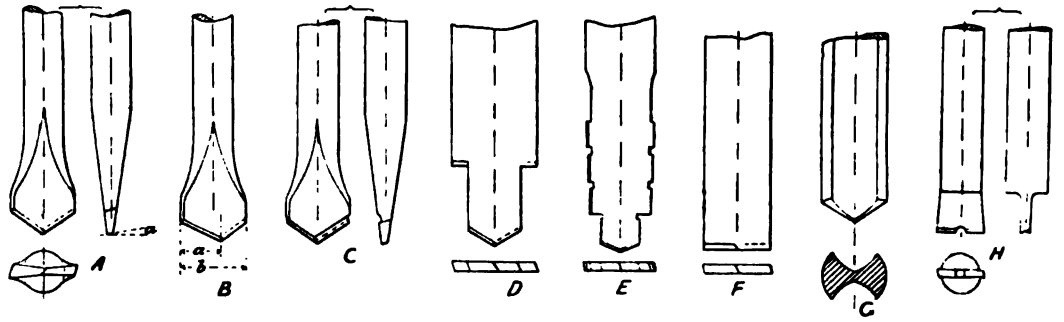


Fig. 163.—Drills.

iron and steel, to 10° or 12° for brass. The angle which the lips make with each other is not important, except that in drilling thin sheet metal a more obtuse angle is desirable, to prevent wobbling as the point gets through the metal. The cutting edges of these drills are single-cutting, as distinct from the double-cutting

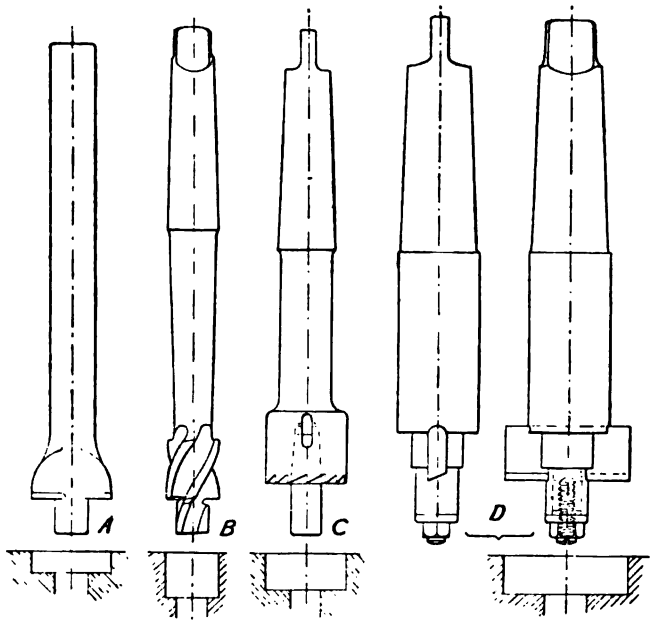


Fig. 164.—Counterbores.

ones of jewellers and light metal-workers, which have no place in engineers' work. The lips are produced by forging the flat, and then grinding to shape, the important thing being to have the lips of equal length. If they are unequal, as at B, the hole will be too large, being of diameter equal to twice the radius *a*, the total diameter *b* having no control over the size. Moreover all the work of cutting will be thrown on the long lip. Neither will the hole be parallel, but the wobbling of the drill will cause the hole to get larger at the bottom.

To increase the efficiency in fibrous metals, rake is often given to the front of the lips, as at C, the chief objection to which is that it cannot be preserved intact long, owing to re-grinding causing obliteration; the twist drills also render this expedient of less use than formerly. Many special adaptations of the flat drill are of great service in cast iron and brass work, especially for lathe use, in originating holes or finishing cored ones. They cut freely, can be formed easily from flat steel, and admit of free escape of the chips; reamering may be done subsequently, according to the degree of accuracy required. D is a pattern having many variations, the example shown being for drilling to two different diameters in the same piece of work. Several shoulders may be produced in this manner, by forming the drill to suit. Radii and curves can be included. When a long hole is to be drilled, advantage may be taken of staggering, as at E, a series of notches being cut so that the chip breaks up into short pieces, causing easy working, and rapid removal of

cuttings. This drill bores slightly tapered, with a smaller recess at the bottom. A reamer follows the drill, making the shouldered portions merge into each other, and finishing to size. For holes which are flat at the ends, F is used, either by itself, or following a previous drill.

The fluted drills, G, are most serviceable in brass, because they do not choke like the twist drills do, and they are used much in lathes, and turrets. Another advantage, chiefly appreciated in small sizes, is that the straight flute type does not twist and run through rapidly when emerging from the hole, a prolific source of breakage being thus avoided. H is the slot-drill, employed for cutting key and cotter-ways. A travelling movement is imparted to the work or the tool, so that a groove is produced. The little hollow cut out at the bottom gives better clearance in cutting. The Twist Drills will be found under that heading.

The Counterbore, which is a form of drill, enlarges holes for the reception of screw and bolt heads, &c., concentricity being ensured by the use of a pin, which gives the term *pin-drill*. The forged type, Fig. 164, A, has the pin solid with the lips and shank. B is a better cutting type, having flutes, in twist drill fashion, which give increased cutting efficiency. C has a removable pin, driven in a taper hole, and removed with a cotter wedge; different sizes of pins may be substituted. The teeth are like those of a milling cutter, the chief objection to the style being that of choking. D is a very useful pattern, with a removable blade held in by the pointed set screw; the pin is in the form of a bush, held on by the nut and washer, which allows of substituting different diameters, to suit the drilled hole. The cutter is removed for sharpening, which is a useful feature of this tool.

Speed of Drills.

The following table shows the revolutions per minute for drills from $\frac{1}{16}$ in. to 2 in. diameter, as usually applied. Oil drills can usually be run 25 per cent. faster.

Diameter of Drills, Inches	Speed for Wrought Iron and Steel.	Speed for Cast Iron.	Speed for Brass.	Diameter of Drills, Inches.	Speed for Wrought Iron and Steel.	Speed for Cast Iron.	Speed for Brass.
$\frac{1}{16}$	1,712	2,383	3,544	$1\frac{1}{16}$	72	108	180
$\frac{1}{8}$	855	1,191	1,772	$1\frac{1}{8}$	68	102	170
$\frac{3}{16}$	571	794	1,181	$1\frac{3}{16}$	64	97	161
$\frac{1}{4}$	397	565	855	$1\frac{1}{4}$	58	89	150
$\frac{5}{16}$	318	452	684	$1\frac{5}{16}$	55	84	143
$\frac{3}{8}$	265	377	570	$1\frac{3}{8}$	53	81	136
$\frac{7}{16}$	227	323	489	$1\frac{7}{16}$	50	77	130
$\frac{1}{2}$	183	267	412	$1\frac{1}{2}$	46	74	122
$\frac{9}{16}$	163	238	367	$1\frac{9}{16}$	44	71	117
$\frac{5}{8}$	147	214	330	$1\frac{5}{8}$	40	66	113
$\frac{11}{16}$	133	194	300	$1\frac{11}{16}$	38	63	109
$\frac{3}{4}$	112	168	265	$1\frac{3}{4}$	37	61	105
$\frac{13}{16}$	103	155	244	$1\frac{13}{16}$	36	59	101
$\frac{7}{8}$	96	144	227	$1\frac{7}{8}$	33	55	98
$\frac{15}{16}$	89	134	212	$1\frac{15}{16}$	32	53	95
1	76	115	191	2	31	51	92

These speeds should seldom be exceeded. Feed per revolution for $\frac{1}{4}$-in. drill, ·005 in.; for $\frac{1}{2}$-in. drill, ·007 in.; for $\frac{3}{4}$-in. drill, ·010 in.

Drill Chuck.—Drill chucks differ from those used in gripping objects for lathe turning in their relatively greater length of jaw, and in the small capacities afforded, 3 in. diameter being an unusual size, and most ranging below 2 in. Four common patterns are illustrated in Fig. 165.

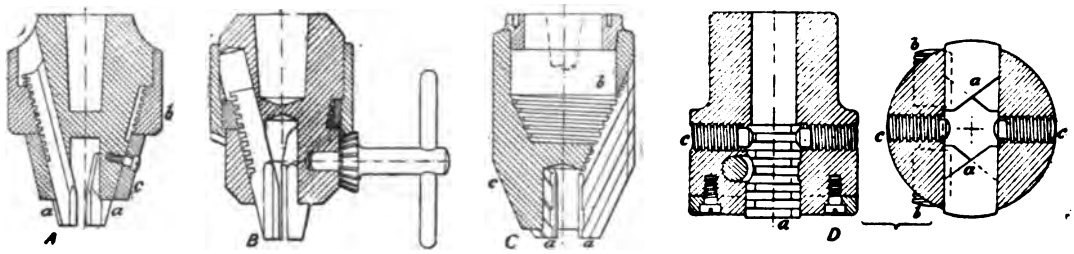


Fig. 165.—Drill Chucks.

The Skinner, A, a type representative of many others, has three jaws, *a*, moved simultaneously by a knurled nut, *b*, which thrusts them along by their threads cut on the back. The cap *c*

retains jaws and nut from dropping off. The Jacobs is somewhat similar, B, but has the outer ring rotated by a ring of teeth, operated with a bevel pinion formed with the handle, and removed after tightening up. The Whiton chuck, C, has broad jaws, *a*, guided by shouldered grooves, and fed by a coned thread cut on the central core, *b*; the body, *c*, is knurled on the outside as a grip for the fingers.

The Westcott, D, a more powerful type, has two serrated jaws, *a*, moved to or from the centre simultaneously by a right and left hand screw *b*. As an additional drive, when necessary, two side-setting screws, *c*, are fitted, to press on the drill shank. Many other chucks owe their gripping power to jaws moved by a right and left hand screw like the Westcott. A positive drive is secured in some by providing a slotted plate at the bottom of the recess, into which the flatted tang of the drill lies, and is so driven positively, independently of the friction of the jaws on the shank. Taper shank drills are gripped with the help of an insertion sleeve or bush.

A recent chuck of Swedish origin, the Grönkvist, has no screws, but acts by inclined grooves within the body, which cause three rollers to advance or recede from the drill shank. The chuck is opened while the machine is running by lightly grasping the knurled outer shell, which causes the rollers to run up the grooves and open out. After inserting a drill, the rotation of the spindle closes the rollers tightly, the action of drilling only serving to make the grip more secure.

Drilled Holes.—A term used to distinguish such holes from those cast, or reamered, or ground, which results in various degrees of accuracy. In much work drilling alone is sufficiently accurate for the purposes required, but in high-class mechanisms, and in certain portions of ordinary jobs, more finish and truth is secured subsequently to drilling, either by reamering, or by lapping, or grinding out. Thus a drilled hole may be quite good enough for the insertion of a bolt, or pin, but too rough for the nice running of a spindle, or shaft. The distinction has therefore to be made on shop drawings, whether holes are cored, drilled, reamered, or lapped.

Drill Gauge.—An angular sheet-metal gauge employed for testing the points of twist and fluted drills. The term is also applied to a flat steel gauge, having a number of differently sized holes, in gradations, used for testing flat drills when making or grinding them. It ensures accurate results, and saves setting calipers for the work each time. A similar class of tool is the "tapping-drill" gauge, the holes in which indicate what drill to select for a hole to be subsequently tapped, the sizes being stamped on the face of the gauge by each hole.

Drill Grinder.—The common flat drill is most usually ground or sharpened on an ordinary emery wheel machine, with or without a slide rest, the accurate centring of the point being ascertained by a drill gauge, or by measuring the length of each lip with a rule. Water must be used to prevent undue heating.

Twist-drills may also be ground by hand, and good results obtained, but it is more economical to do them by machine, when large numbers are in use. *See* **Twist-Drill Grinder.**

Drilling.—Drilling is performed in practically all classes of metal working, from the tiniest dimensions up to massive engineers' work using solid drills of 6 inches or more diameter. The term is usually restricted to the production of holes in solid metal with drills that have no loose cutters, any other class merging into boring. It is done by hand braces, breast drills, ratchet braces, machines of all types, vertical and horizontal, by lathes, and also in certain machines which combine other functions, as boring, and milling. The flat, the straight-fluted, and the twist drills monopolise nearly the whole field, a few special types only being used in certain cases.

One of the most difficult operations in drilling is to locate the hole just where wanted, because the drill tends to wander to one side of the centre-pop made as a commencement. When a drilling jig is employed there is of course no trouble on this score, as the jig bushing rigidly coerces the drill body. In ordinary work, however, it may be necessary to throw the drill over to one side, by punching or drifting with centre punch, or round-nose chisel, in the shallow impression made by the drill point, and thus leading it to cut in a fresh position. This often

has to be repeated two or three times in some instances. To enable the operator to see the trend of the drill, a compass circle is struck from the original centre-pop, of a diameter the same, or larger than that of the drill, so that the concentricity or otherwise of the drilling may be noted as it proceeds. After the point has fully buried itself in the metal there is no chance of rectifying any inaccuracy, so that the correction must be effected at an early stage.

The removal of chips is another important question which affects drilling, more especially in deep holes. Here the fluted and the twist-drills show to great advantage, owing to their conductance of the chips back out of the hole. This removal is effected more properly when an oil supply pipe is fitted, leading to the drill nose, and so washing out the cuttings as fast as they are produced.

Rapidity of output in drilling is promoted by lubrication, by the multiplication of spindles, by the use of high-speed steel, and by keeping the drills perfectly sharpened. The last-named point is a most important one in securing the highest efficiencies, so that a proper system of drill grinding for all the machines in a shop pays in results obtained.

Drilling Jig.—*See* **Jigs.**

Drilling Machines.—These exist in a large variety of styles and sizes, both in common designs, and those specially devoted to particular work. They are vertical, or horizontal, or capable of angling; single or multiple-spindle, combined with tapping devices; fixed or portable, hand, or power-driven, with hand or self-acting feed. The feed may be imparted either by moving the drills, or the work. The feed may be either by screw, or lever, or, in the light types, by sensitive devices, which enable delicate pressure to be imparted to small drills, so that risk of breakage by over-forcing is mostly avoided.

In attempting to classify the various types of machines we first encounter the most primitive pattern, modelled on the old drill press, in which the spindle is fed down by a pivoted lever. This has many representatives nowadays, notably the blacksmith's drills, driven by handle and gears, with a flywheel included, and a lever connected to links, pressing a block on the spindle end. Modifications of the design are numerous, the sensitive bench drills having many points of resemblance thereto, but being of a more refined construction, driven by belt pulley, or friction disc, and fed alternatively by rack and pinion, with a spring return.

The pillar drills are a larger class of the same design, but with more powerful drive, and means of feeding by power in addition to hand. The pillar style (with which is allied the wall type) is adapted for pieces of moderate width only, because of the limit imposed, due to the presence of the pillar. The work moreover must be located exactly under the drill by shifting it about until the centre of the desired hole comes right. This is awkward in heavy jobs, so that here the radial drill steps in and fills a useful place. Its long arm projects out many feet over the base plate or table, and in addition to the sliding of the head along the arm, the latter slews, so that once the work is dumped down on the plate, the drill can be brought to any desired position within its range, and consequently a number of holes may be drilled at various locations without moving the work. Radial drills are attached to walls, as well as being self-contained on their own pillars. The heavier sizes have all the motions performed by power, including the movements of the arm, and of the head, enabling adjustments to be effected rapidly, without imposing laborious work on the operator.

There is a special style of radial machine, used principally in boiler and plating shops, which has two or three hinged portions, reaching out a long distance from the wall, to deal with large areas of plates, when drilling or countersinking. The motion is transmitted by belts passing around pulleys mounted on each pivot, until the end spindle is reached, the drive being thus unaffected by any angling of the arms.

Multiple-spindle drills occur in several varieties. A common design is that of two uprights supporting a cross-rail on which is carried two or more drilling heads which may be adjusted to variable distances apart, for operating on rods, plates, bars, links, with several holes in each, or on separate pieces, one attendant looking after the machine. Sometimes the spindles feed down, occasionally the

table moves upwards. Sensitive machines are constructed with several spindles, from two to four; gang drills have six or more. Another class of machine has the drills adjustable in a peculiar manner. All the spindles are driven by gears from a common head, but they diverge therefrom, being fitted with universal joints, so that they may be adjusted and locked at the lower end in any desired pattern, circular or otherwise, so obviating the necessity for employing a drilling jig. Feeding is done either by moving the head bodily with all its drills, or by raising the table. The economies effected by these machines are obviously great, considering that from a dozen to twenty drills may be operating on a piece simultaneously.

Portable drills constitute a rapidly increasing class, especially in shops doing medium and heavy work. It is cheaper and quicker to take a portable machine to a massive piece of work than to transport the latter to a fixed machine. On out-door jobs also the portable drill ousts the ratchet type where power is available for driving. The principal methods of driving are pneumatic, and electric, the rope and belt drives being less handy in most cases.

Examples of the various types of drilling machines will be treated under appropriate headings.

Drilling Pillar.—The post carrying the arm against which the pressure of the ratchet drill is taken; it is termed also "John Bull" and "Old Man." A pillar is also used to carry some types of power-driven portable drilling machines.

Drip Can.—A can of sheet metal or cast iron supported above the work in lathes, bolt-screwing machines, capstan lathes, milling and some other machines, to deliver a stream or succession of drops of suds or oil upon the tools and work, a tap fitted in the pipe allowing of regulation. It has been superseded to a large extent by the forced lubrication supplied by pumps, which give a more copious volume of lubricant over the work, and keep up the supply without any attention on the operator's part.

Drive Pipe.—The inlet pipe of a hydraulic ram.

Driver, Driving.—A common prefix which is nearly self-explanatory, special cases excepted. In a pair of gears, driver signifies the wheel which actuates another, the driven. In trains of gears there may be two or more drivers, actuating as many driven wheels. A driving, or live axle is one that receives motion from the prime mover, as the crank axle of a locomotive, and communicates it to the trailing, or following axle; and the axle springs are driving and trailing springs respectively. The wheels are similarly named. Belts are driving tension members, and their pulleys are driving, and driven respectively. A driving chain is one that exercises positive action, without slip, being either a common link chain fitting in recessed sheaves, or a pitch chain over sprockets. A driving chuck is either one fitted with a driver, or it is a bell chuck. A driving fit is one which requires pressure, or hammer blows, to cause a shaft or spindle to fit its bored hole, and the term driving home is commonly applied to the fitting of parts by hammer blows. Driving gears is a generic term to denote systems of toothed wheels, belts, chains, &c., that communicate motion. The driving side of a belt is that next the pulley, and also the lower or slack side.

Lathe Driver.—The common lathe driver takes the form of a pin held in the small face, or *catch plate*, to engage with the work, or with a carrier fixed thereon. In Fig. 166, A represents the ordinary type of plate, with the pin held in by a nut. As it is sometimes awkward to have the pin sticking out to full length, adjustability is provided for, as in B and C, the first with screw and nuts, the second with clamping set-screw. On large face plates for wheel lathes the driver pins are held in cast-iron brackets bolted to the plate.

The unequal driving produced by these one-pin devices causes the *Clements'* to be preferred, the twisting motion in this being equal on both sides of the work. It is evident that simply sticking two pins in a plate would not ensure double driving, since only one would touch the carrier. The Clements' device, D provides sufficient play, by means of a slotted plate *a*, slipping on the face of a plate *b*, to enable both pins to fetch against the carrier; *a* is driven by studs *c*, *c*, screwed into *b*. The

driving pins *d*, *d* are tapped into *a*. Though this driver is not seen to any great extent on ordinary lathes, it is extensively employed for such work as shaft turning. In a double driver by J. Parkinson & Son a safety device is embodied, by casting a cylindrical body in one with the driving horns, so that the carrier is completely enclosed, and the clothes cannot catch in it. When the bent-tail carrier is used, the driver takes the shape of a plate with a slot only in it, E, engaging with the tail.

On the index centres of milling machines a modified style is adopted, F, with flat sides, and having set-screws so that the carrier tail may be pinched firmly, to prevent backlash, which would be fatal to accurate dividing. On some screw milling machines the same provision is made by introducing a sliding block fitting on a face plate, and closed up and clamped firmly by a set-screw.

Drop.—Denotes the period when ebullition ceases in the pig boiling process for making malleable iron. Also corresponds with the stage of complete decarbonisation of the metal in a Bessemer converter at which the flame shortens, or drops.

Drop Bottom.—Relates to certain cupolas from which the residuum of the day's cast is discharged by opening a hinged bottom, instead of raking it out through the slagging hole. *See* **Cupola.** Also contractor's boxes or skips which have hinged bottoms, that open and fall downwards. *See* **Bag Work** and **Skip.**

Drop Forgings.—Forgings stamped under drop hammers. They are thus distinguished from other forgings made in dies, under other conditions. *See* **Forging Dies.**

Drop Hammer.—A forging hammer which falls by gravity, and is lifted by the friction of a belt or board, operated by hand or by steam. It differs from a steam, or pneumatic hammer in not being provided with a cylinder and piston for direct delivery of the blow. It is more suitable for the smaller forgings than an ordinary steam hammer is, because the blows are capable of regulation by the forger. *See*

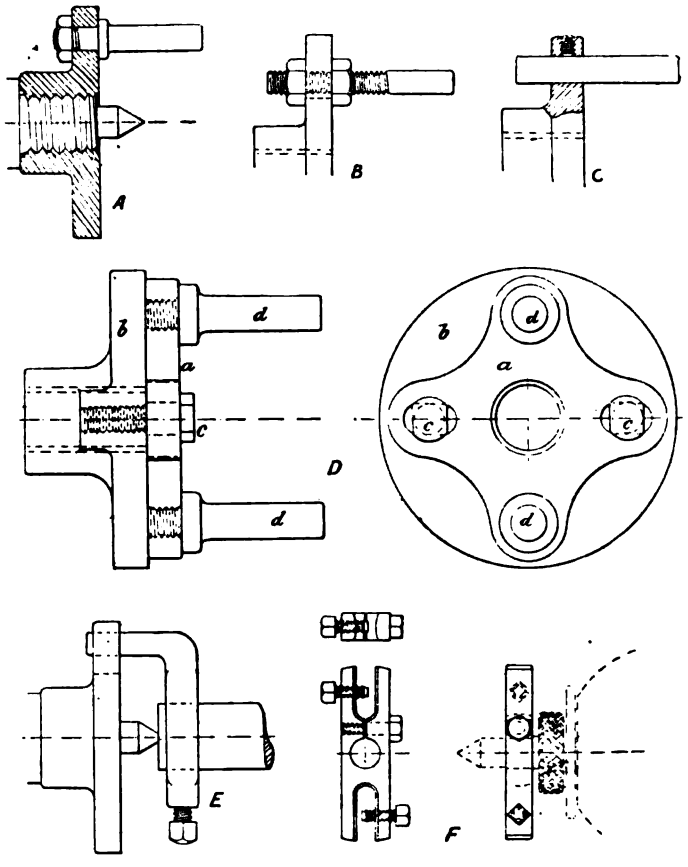


Fig. 166.—Drivers.

Board Drop Hammer, Belt Drop Hammer, Brett Lifters.

Drop of Potential.—A "dead" conductor, before any current can be passed along it, must first have its own reluctance to conduction, or "specific resistance," overcome. This causes a drop of pressure in proportion to its resistance. *See* **Ohm's Law.**

Drop-Out.—An accident which sometimes happens to a foundry mould rammed too loosely, or having insufficient support in the form of stays, rods, or lifters. Portions of, or the whole of the sand in such cases may fall out.

Middle parts destitute of bars are more liable to this mishap than tops or bottoms. It is liable to occur at the time of separating, and lifting box parts, or of turning them over.

Drop Press.—A **Drop Hammer.**

Drop Tests.—*See* **Impact Tests.**

Drop Trip, or **Drop Worm.**—A device by which the feed worm of a milling machine is dropped out of engagement with its worm wheel at the termination of a traverse. The worm box with its bearings is hinged, and dropped bodily by a trip lever suitably set.

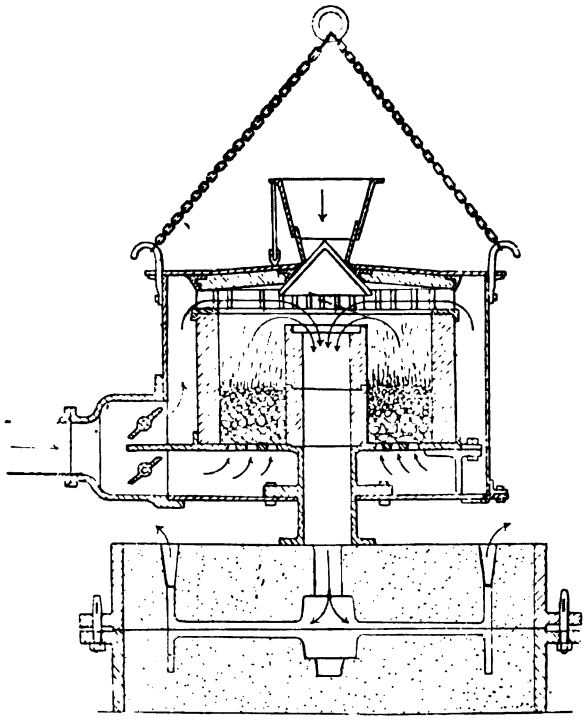


Fig. 167.—Drying a Mould with Portable Stove.

Drop Valve.—A term applied to a double beat or equilibrium valve used on steam engines. The term distinguishes it from the slide and the Corliss valves. An example occurs under **Compound Engine.**

Drowned.—Relates to the reaction type of turbine, in which the buckets must be filled with water, and must therefore be wholly submerged.

Drum.—A hollow vessel or a cylindrical vessel, with some forms derived therefrom. The hoisting barrel for a crane is a drum. *See* **Crane Drums.** A very wide belt pulley is a drum. A steam drum is the cylindrical receiver over a water-tube boiler. The top of a capstan is a drumhead. A smith's hammerman is a drummer.

Drum Armature. — An armature having all its conductors arranged upon its outer circumference. Usually these conductors are buried in slots cut lengthwise in the iron core of the armature. A positive driving effect upon them is thus obtained, and they may be run at much higher peripheral velocities. The speed of these conductors is an important factor in the power and efficiency of the dynamo.

By the use of drum windings disposed in slotted cores, the tendency of the conductors to slip when driven at high speeds is overcome, so that this method of construction is now always employed. The whole of the copper conductors being in active use, added to the higher peripheral speed, makes this a very efficient type of armature. *See* **Dynamo.**

Drunken Saw. — A circular saw mounted diagonally on its spindle, so that it can be swivelled to produce a wobbling or drunken motion, enabling grooving, tenoning, and trenching to be done, in lieu of employing a cutter-head. The swivelling is effected by carrying the saw between two discs, which pivot upon pins in the central hub, locking being effected by a convex-headed screw set in laterally. Saws from 10 in. to 20 in. diameter are fitted thus.

Drunken Thread.—*See* **Screw Threads.**

Dry Brush. — A hand brush used in foundries for removing loose particles of sand from the joint faces of moulds.

Dry Cell. — A primary electric battery having its electrolyte in a plastic, instead of liquid state, in order that the cell may be portable, and unaffected by heat or cold. *See* **Batteries—Primary.**

Dry Grinding.—*See* **Grinding.**

Drying Moulds.—This is done in stoves, or in the case of large work, *in situ*. For the

latter, devils are used, or heaters of iron when the drying is of a local character only. In present-day practice, heating installations are often laid down. Shops are served with pipes fed by mains, and connected to a number of portable stoves. Cold air driven by a fan, and controlled by a valve, enters the stove through a pipe of about 3 inches bore, and burning in a coke fire lit within the stove, is heated. The products of combustion and a supply of air brought over the top of the incandescent fuel to a tube, are conveyed to the inside of the mould. The diagram, Fig. 167, illustrates the operation of the furnace drying of a pulley mould on the floor, and Fig. 168 another type of portable furnace.

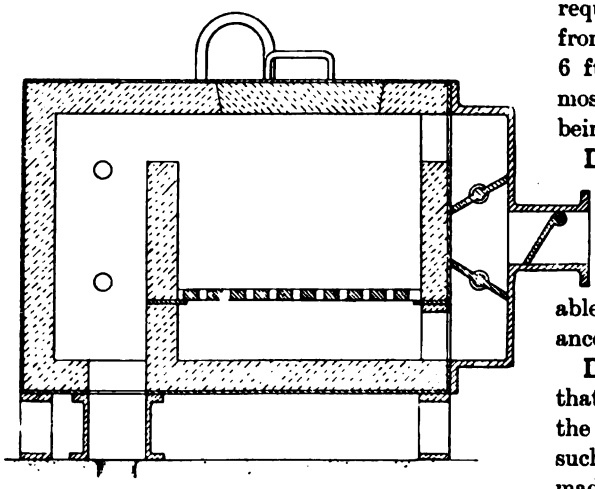


Fig. 168.—Portable Drying Stove.

Drying Oils.—Vegetable oils which absorb oxygen from the air, becoming hard and solid. Linseed, hemp, poppy, colza, and almond belong to this group.

Drying Stove.—This is often used as a synonym for core stove. But strictly, it signifies one that is used for general purposes, as for the drying of large moulds in dried sand, and in loam, as well as for large cores. The term core stove is generally restricted to a smaller structure employed by the core-makers only. But either term is often used indiscriminately.

In strictness, a drying stove is one of large dimensions. It is built of brick, with a vaulted roof. The walls are tied together above, just beneath the arch (which has but a slight curvature), with bolts. The stove is closed at the back with a brick wall, and in front with sheet-iron doors, counterbalanced, which may or may not be brick lined (usually not). Heating is effected by a coke fire built sometimes within the stove in the floor, sometimes without at the back, or on one side. In modern practice producer gas is largely used, being cleaner, and under better regulation than a coke fire. An essential in a stove is a line of rails for the carriage, on which the work is run in from without, and drawn out again when dried. It is of iron, low in height, in order to give head room for moulds.

The dimensions of drying stoves vary with requirements. On an average they range from about 12 ft. to 24 ft. in length, by from 6 ft. to 12 ft. in width, and height. They are mostly built outside the foundry, the doorway being in the foundry wall.

Dry Rot.—A fungous disease that attacks old timber. It destroys by absorbing the secretionary matter of the wood, leaving empty, dry tubes. A moist, damp, ill-ventilated atmosphere is that most favourable to this growth, hence the need for observance of opposite conditions.

Dry Sand Moulding.—This term means that the moulds are dried completely before the metal is poured. The methods of making such moulds are essentially similar to those made in green sand. But the sand is of a different character, being strong or tenacious, so that it coheres when dry, while green sand is friable, without cohesion. Being dried also, it can be, and is rammed harder than green, with no evil results, and although very dense when first rammed, it becomes so porous by drying that it requires little venting. It must, however, be thoroughly dry, because, like loam it depends for its venting on its porosity. When imperfectly dried, so that steam is still evolved, casting is very risky, and the more so the colder the mould is allowed to get before pouring. The same risks attend the pouring of such a mould imperfectly dried in its interior that attend the use of cores in a similar condition, because both are vented chiefly by the natural porosity of the material itself. Less

venting, therefore, is required with dry than with green sand.

In corners, angles, and awkward parts it is customary to ram up vent wires, or rods in the mould, long enough to project sufficiently high above the face to permit of withdrawal by the hand when the mould is finished.

Dry sand mixtures will permit of being well swabbed after the withdrawal of the pattern for purposes of mending up, and consolidation, without the risk of scabbing; which is always present when the swab is used too freely in green sand.

Though in dried sand moulds strong facing mixtures are used next the pattern, a weaker is employed for mere box filling, consisting of a mixture of floor sand with proportions of new, strong sand. This, though not strong alone, but somewhat rotten, is suitable for the mere filling, being sustained and consolidated by the stronger facing, and the hard ramming to which dry sand is subjected, and the assistance derived from lifters.

An important detail in dry sand work, wherein it differs from green, is due to the comparative brittleness of its edges. When a common mould is jointed, the joints go back into contact after the withdrawal of the pattern. In dry sand the joint edges are not allowed to come into actual contact again, but they are *finned*, that is, they are squeezed downwards with the trowel immediately that the pattern has been withdrawn; so that while the main body of the sand in the joint still remains in contact, that near the edges is separated by a very small distance, and when cast a fin of metal forms there. The reason of this is that the dry sand, though strong in mass, would, on the exertion of pressure on joints having the slightest want of correspondence, flake away, owing to its brittle nature, while in green sand such does not happen, the latter yielding a little to pressure.

The advantages of dry sand moulding are greater safety and cleanness of surface of the castings, over those made in green sand. Hence it is peculiarly adapted to the making of deep vertical moulds, where the liquid pressure is very great, and where green sand would yield before the metal, and produce lumpy castings. Metal can be poured into a dry sand mould and fall directly on the bottom from a height of 12 ft. or 15 ft. without cutting up the sand at all. Also, less gas being generated from a green than from a dry sand mould, the casting is safer and sounder; though the cost is usually rather more than that of a similar green sand mould. But the cost may be much lessened where dry sand work is followed as a system in shops set apart for it, with stoves, and pits.

Dry sand moulds are cast vertically, or horizontally, according to circumstances. They are well adapted for vertical casting, because the sand is firm, and not likely to be started by slinging in the crane, and lowering into the pit, nor by an inrush of metal falling downwards.

Dry Steam.—Steam in the normal or saturated condition, neither mixed with water of priming, nor superheated.

Ductility.—This is the name given to the property by virtue of which certain solids may be drawn out into a thin wire, or thread. It is a question of the degree of the force of cohesion between the molecules. Most of the metals are ductile, the degree in which this property is possessed being roughly represented in the following order: gold, silver, platinum, iron, copper, zinc, tin, and lead. Iron and copper wires of 2 mm. diameter sustain a weight of 239 and 222 kilos. respectively, while tin and lead wires of the same diameter only support 16 and 2 kilos. respectively.

Duff Gas.—*See* **Gas Producer.**

Dull Metal.—Cast iron which has either been imperfectly melted; or more generally when it has been allowed to stand in the ladle to part with some of its heat, which cooling is often assisted by throwing cold runner heads and risers into the ladle. The term dull does not denote a very precise stage of cooling, since metal that would be dull for a mould of small section would be too hot for a massive mould. The larger the body of metal in a mould, the more reason is there why hot metal should not be used. Hot metal shrinks more, and is more liable to result in draws, to produce sand burning, to cause scabbing, and other evils. On the other hand, if

metal is allowed to become too dull, cold shuts are liable to form, and the metal may even become set before it has been able to fill the finer sections of the mould. The degree of fluidity of the metal is estimated by the eye only, watching the breaking of the surface, which is skimmed for the purpose.

Dulong and Petit's Law.—*See* **Atom**, Vol. I., p. 218.

Dulong's Formula.— Proposed by the French chemist for approximate estimation of the calorific value of any fuel, deduced from the carbon, oxygen, and hydrogen present.

Let C = Weight of Carbon.
H = „ Hydrogen.
O = „ Oxygen.
Then if x = Calories = 8,080,

$$x = C + 34{,}500\left(H - \frac{O}{8}\right).$$

Or if x = B.Th.U. = 14,500,

$$x = C + 62{,}100\left(H - \frac{O}{8}\right).$$

Dummy.—A reverse mould or ramming block upon which an actual mould is rammed. Also a piece of lead used in testing during the cutting of dies for die forging.

Dung.—Horse manure, used for mixing with strong sand to assist in rendering it open, and free venting, due to the burning out of the particles of hay.

Duodecimals.—In working problems occurring in engineering which involve square and cubic measure, it is necessary either to bring all terms (yards, feet, inches) to the lowest denomination, or to represent the lower denominations as decimals of the highest. The method of duodecimals (or cross multiplication) provides an alternative process in which feet and inches are multiplied as they stand. The product of feet and inches gives "primes"; 12 square inches make 1 superficial prime, and 12 superficial primes make 1 square foot. Duodecimals are used more by bricklayers and painters than engineers, though pattern-makers and carpenters employ it in timber measurements, and it is doubtful if the method possesses any great advantages over the ordinary process.

The following example is worked by this method:—

Multiply 5 ft. 7 in. by 4 ft. 5 in.

5	7	
4	5	
22	4	
2	3	11
24	7	11

Multiplying crosswise, 4 ft. × 7 ins. = 28 superficial primes, and this divided by 12 (12 superficial primes = 1 sq. ft.) = 2 sq. ft. 4 superficial primes. Set down 4, carry 2. Next, 4 × 5 = 20, and 2 carried = 22 sq. ft. Then multiply by 5; 5 × 7 = 35 sq. ins. = 2 superficial primes + 11 sq. ins. (since 12 sq. ins. = 1 superficial prime). Set down 11, carry 2; 5 × 5 = 25 and 2 carried = 27 superficial primes = 2 sq. ft. + 3 superficial primes. Adding up, the result is 24 sq. ft., 7 superficial primes, 11 sq. ins. As primes have no place in everyday measurements they may be expressed as square inches, or with the inches as a fraction of a square foot. Thus 7 × 12 = 84 sq. ins.; 84 + 11 = 95; the result then being 24 sq. ft. 95 sq. ins. Or, since the 7 primes $= \frac{7}{12}$ of a sq. ft., and the 11 ins. $= \frac{11}{144}$ sq. ft., the result becomes $24 + \frac{7}{12} + \frac{11}{144}$ sq. ft. $= 24\frac{95}{144}$ sq. ft.

Duplex.—Sometimes the same as double, but not always. In strictness it signifies the duplication of a mechanism, or portion of mechanism. Thus, double rests are always termed duplex rests. The term is used rather loosely.

Duplicate Machinery.—When the breakdown of machinery would involve very serious delay and loss, it is necessary to duplicate the whole of it. This is done in electric lighting and power stations and in private installations. Frequently the two sets are made capable of connection and disconnection.

Dürr Boiler.—A German water-tube boiler. It belongs to the free circulation group, in which the tubes are inclined to a few degrees from the horizontal. It is not divided into elements, but the tubes are connected to a flat water space, which discharges into a drum

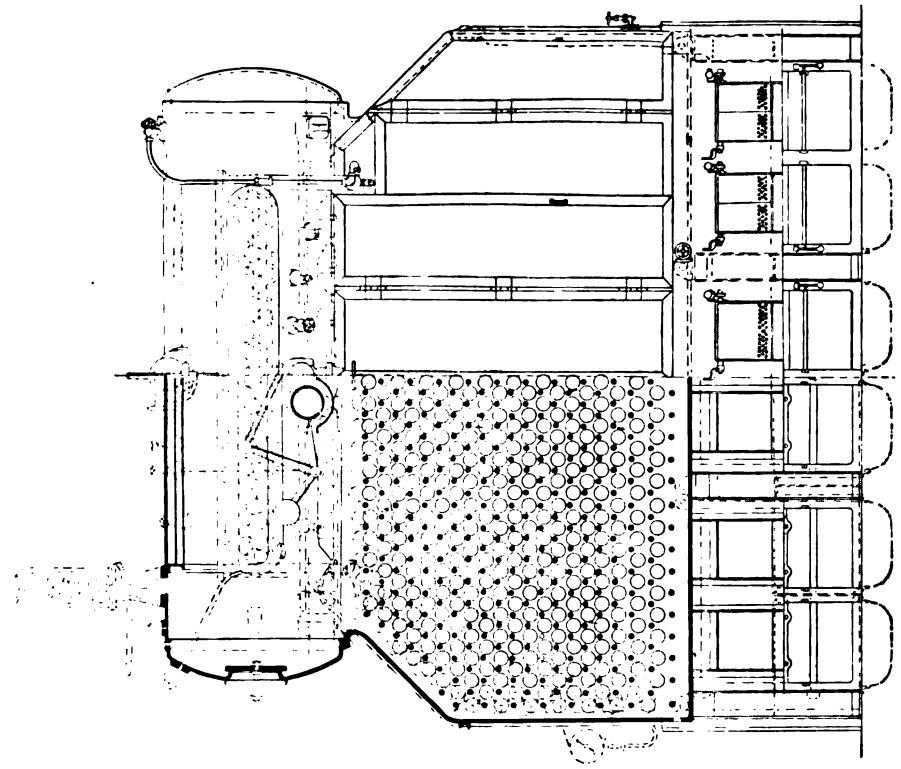


Fig. 170.—Part Transverse Section, and External Elevation.

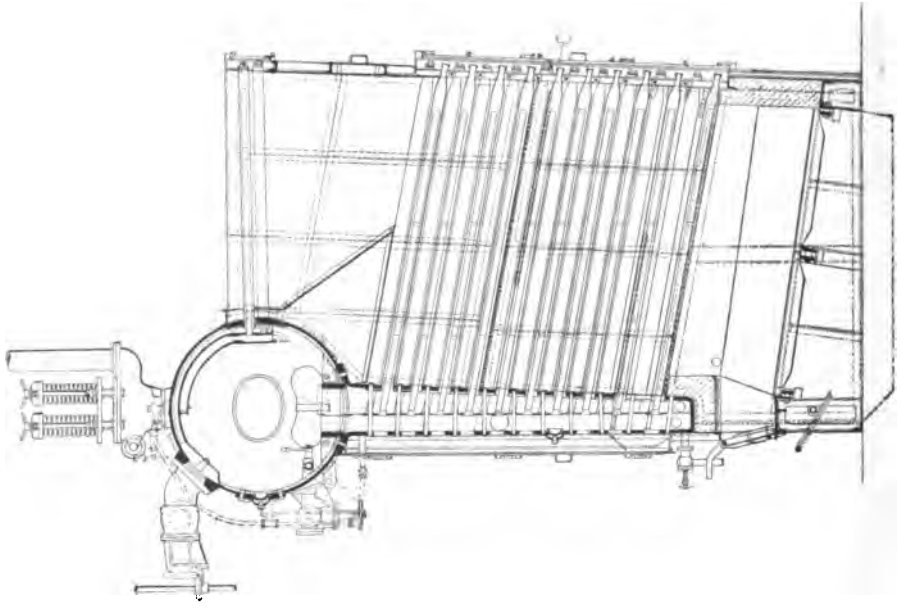


Fig. 169.—Longitudinal Section.

Dürr Boiler (Düsseldorf-Ratinger Röhrenkesselfabrik vorm. Dürr & Co.).

above, inclined to the same angle as the tubes.

The Dürr boiler is designed both for land and marine service, with differences in the two types. The primal principle is that of the well-known Field tubes, only in this case the tubes are inclined. The outer tubes are closed at the lower ends and communicate at the other with one side only of the vertical water chamber, see Figs. 169, 170. The inner tubes, open at both ends, are in communication with the other side of the water chamber and with the outer tube. The circulation is promoted, and steam and water separated thus:—The water evaporated in the outer tubes ascends the inner side of the water chamber, and so rises to the steam drum where the steam is collected. Thence the water present descends through the outer or front side of the water chamber, and mixing with fresh feed water, passes down the inner tubes, and so into the outer tubes, replacing the water evaporated in them. The steam travelling upwards is thus kept separate from the feed moving downwards.

The water chamber or heater is welded throughout and stayed. The water tubes are fitted at the front end with welded conical mouthpieces, and expanded into holes in the back plate of the water chamber. The inner or circulating tubes are jointed with conical ends into the partition plate of the water chamber. A superheater is placed within the boiler and is an integral part of it. The illustrations show a number of details which explain themselves.

Dust Exhausting Devices.—The applications of fans to the exhaustion of dust from workshops and machines have grown greatly during recent years. They are used in fettling rooms, in wood-working establishments, and others, and in grinding machines. In wood-working shops an exhausting fan is fixed in the course which the dust is intended to traverse. It is received in pipes (*trunking*) and drawn or blown towards the fan. It is directed to the trunking by hoods, or hoppers, or through *sweep-ups* (holes in the floor through which tubes communicate with the trunking). It is discharged into a dust collector, or exhaust house, to be fed into baskets, or sent to the stokehold. In some cases a separation is effected between the sawdust and shavings, through a sieve actuated by a tappet motion. Examples of dust exhausters will be found in some of the machines illustrated in these volumes. *See* **Disc Grinder, Grinding Machines.**

Dutch Wheel Crane.—An old form once used on quay walls, worked by men walking within a hollow wheel of large diameter on the same axis as the barrel, of small diameter.

Duty.—The duty of an engine is the way of expressing the number of millions of pounds raised one foot high by a bushel, or 94 lb. of Welsh coal, but 100 lb. is also taken. The term is hardly used in relation to any engines except the Cornish, where it seems to have originated. The average annual duty of Cornish engines in 1840 was about 55,000,000 foot pounds. Rates as high as 120,000,000 foot pounds have been reached. New engines working in shallow mines gave the best results. As the mines deepened, and the steam worked less expansively, the duty dropped by 30 or 40 per cent. The reason why these engines were so efficient was due to using the steam expansively, by jacketing, and by measures taken to prevent condensation.

The feature in the Cornish engine which made for economy was that the steam did not escape immediately to the condenser after thrusting the piston down. When the weight of the pump rods pulled the piston up again, the steam passed to the bottom of the cylinder, and at the next down stroke escaped to the condenser. Hence the temperature at the top of the cylinder never fell so low as that of the condenser.

D-Valve.—Derives its name from the resemblance of its longitudinal section to that letter. It is not used in its plain form for large engines, nor for those having a cut-off earlier than half stroke of the piston. Its length of travel, and friction are both excessive, hence the advantages secured by the double and treble ported types. The *long-D* valve is a very old form, long enough to cover the ports at each end of the cylinder, and in which the D section was transversely to the longitudinal axis. The steam passed through the valve from one end to the other, and therefore the valve should have been nearly in equilibrium. But the friction was excessive and the difficulty of fitting great, and the form is now obsolete.

Dynamic Load.—A live load.

Dynamics. — Dynamics is the study of matter and motion, the investigation of the motion of a body and the force producing it. The science is subdivided into Statics and Kinetics—the former dealing with the forces that compel rest, or prevent change of motion, the latter with those forces which cause motion or change of motion.

The foundation of the whole science rests upon Newton's three great laws of motion.

Law 1. Every body continues in a state of rest or of uniform motion in a straight line except in so far as it is compelled to change that state by force acting upon it.

Law 2. Change of motion of a body is proportional to the force acting on the body, and takes place in the direction of the straight line in which the force acts.

Law 3. To every action there is an equal and contrary reaction.

At the outset it is obviously necessary to seek and adopt three fundamental units for the three factors which enter into dynamical questions, (*a*) space, (*b*) mass, (*c*) time. Although our notions of these things are imperfect and merely relative, it is a simple matter to adopt representative units. Two systems are in use, the British and the Metric, the former being called the F.P.S. or foot-pound-second system, and the latter the C.G.S. or centimetre-gramme-second system. These units need no explanation. From the standards of length and time, we pass to the idea of velocity, "uniform" when the body passes over equal spaces in equal times; "variable" when it does not pass over equal spaces in equal times; "accelerated" when the velocity increases, and "retarded" when it decreases.

In considering the motion of bodies we are confronted with the conception of "force." What force is it is impossible to say. Its effects are, however, everywhere perceived, and hence force is defined as that which changes or tends to produce a change in a body's state of rest or motion. To gain a complete idea of any force it is necessary to know (1) its point of application, (2) the direction of the force, (3) its magnitude. When two, three, or more forces act on a body, their action is studied and graphically represented by the three famous propositions and corresponding diagrams of the parallelogram, triangle, and polygon of forces. The process of replacing several forces by one single equivalent force is known as the "composition of forces," and the reverse operation, that of substituting two or more forces for one single force, is the "resolution of forces." In the first case the several forces are compounded into a resultant; in the second case the single force is resolved into its components.

If the forces in question do not act at one point but at different parts of a body, and in parallel directions, they are "parallel forces," and may be like or unlike according as they act in the same or in opposite directions. A pair of such equal and opposite forces produce a "couple," and the product of either of the forces into the perpendicular distance between them is the "moment" of the couple.

Gravity is universal, and is also the most easily studied of the various forces of Nature. The motion due to gravity is seen in the acceleration of bodies falling from rest, or projected downwards, and in the retardation of bodies projected upwards. Friction and its laws, centrifugal force, the swinging of pendulums, and other questions are closely related to that of gravity, which acts as a modifying influence on other forces. On the other hand, friction largely modifies the effects of force, and so is of great importance, especially in engineering practice.

Force may be considered as acting in the form either of a push or a pull. Unless the forces acting on a body are in equilibrium, or are at right angles to the direction in which the body moves, work is done, and the consideration of the work that can be obtained from a body leads to the great question of energy. The conversion of work to a convenient from an inconvenient form leads to the venerable classification of the mechanical powers:—Levers, the wheel and axle, pulleys, the inclined plane, the wedge, and the screw.

For the discussion of the points mentioned above, reference must be made to articles under special headings, such as **Acceleration, Centre of Gravity, Elasticity, Energy, Force, Friction, Gravity, Levers, Velocity,** &c., &c.

Dynamite. — An explosive compound invented by the Swedish chemist, Alfred Nobel, in 1866. Nitro-glycerine (formed by the action of nitric acid on glycerine) had been discovered by Sobrero in 1846, but the danger attending its use as a liquid had considerably limited its usefulness. Nobel experimented with various absorbent materials, and eventually discovered one which has never yet been improved upon. This is "Kieselguhr," a silicious earth consisting of fossil remains of diatoms, occurring in Hanover (hence its German name), in Scotland, Italy, and Norway. After being calcined, crushed, and sifted, kieselguhr absorbs three or four times its weight of nitro-glycerine. Thorough mixing of liquid and absorbent is ensured by hand-kneading, first in troughs and then through fine sieves. Finally piston-presses mould the mixture into small cylinders, and these are wrapped up in waterproof paper ready for use.

In colour, dynamite is reddish-brown. It is sometimes greasy owing to the exudation of nitro-glycerine. It freezes at about 39° Fahr. and must be thawed before use. This is a risky operation, and is performed in a "warming pan," a zinc vessel enclosing another one, the space between being occupied by hot water below 158° Fahr. Its specific gravity is 1·59 to 1·65.

When ignited, dynamite burns quietly, but if great heat is engendered it explodes. Dynamite is exploded in blasting operations by a detonator containing fulminate of mercury (obtained by the action of nitric acid and alcohol on mercury). The force developed by the explosion of dynamite is enormous—one kilogramme developing 7,250,000 foot pounds of energy in one fifty-thousandth of a second.

By substituting other absorbents than kieselguhr and varying the composition, many kinds of dynamite have been produced. The chief absorbents are wood-meal, wood-pulp, and charcoal, while the nitrate and carbonate of sodium, sulphur, magnesium carbonate, and potassium chlorate are frequently included among the constituents. Nitro-glycerine is of course the essential constituent, and forms the greatest percentage in the composition of any true dynamite. The following is a list of the commoner dynamites used:—kieselguhr dynamite, carbonite, stonite, carbo-dynamite, meganite, lithofracteur, rhexite, Hercules powder, Vulcan powder, vigorite, Atlas powder, Judson powder, and safety nitro-powder, the last six being American dynamites. *See* **Blasting.**

Dynamo.—The dynamo as a practical commercial machine dates only from the year 1876, when M. Gramme perfected a dynamo for series arc lighting.

It is not possible here to attempt a historical sketch, nor, in view of the vast improvements which have been made upon them, would it be of advantage to describe the older types of dynamos. It is proposed, therefore, without going into the theoretical details and mathematics of their design, to give a short description of the various parts, their construction and functions, such as may be useful to the practical engineer.

Points in Development.—The evolution of the dynamo has been rapid, and in its comparatively short history it has gone through considerable changes in appearance and design. But whilst improvements in its efficiency as a converter of mechanical energy into electrical power have been made, and machines can now be built to give out at their terminals as much as 94 per cent. of the engine power applied to their shafts, improvement has been effected chiefly in the direction of making fuller use of the materials employed in their construction. Some of the improvements in armature design have effected economies of copper. The positive driving of the conductors by the use of slotted cores, the laminated building up and better ventilation and cooling of the core, thus minimising the internal eddy current and hysteresis losses, have also been favourable to the better utilisation of the material. The coils being now formed before being put on the core, armature construction is rendered much simpler and more mechanical. A better knowledge of the magnetisation of iron has enabled the designer to work nearer to saturation point in the field magnets; and all these improvements together have rendered possible the building of larger, more efficient, and more economical machines, so that dynamos giving

outputs of thousands of kilowatts are now installed in numbers of power stations.

Construction.—The dynamo may be said to consist of two systems, the magnetic, and the electrical. The theory of the electric generator may be put thus:—"When a moving conductor enters a magnetic field, currents are produced in it by magnetic induction." These induced currents may be collected, their powers added together, and electricity, collected at its terminals at suitable pressure, may be carried from the dynamo to any locality by conducting wires or cables, and then be made to give back the mechanical energy expended in moving the armature conductors through the magnetic field.

The dynamo is built up upon a suitable cast-iron bed-plate, and consists of five principal parts, namely, the field-frame, the electro-magnets, the armature, commutator, and brush-gear.

The *field-frame* is a ring of cast iron or mild steel of suitable diameter and width, and having supporting feet to secure it,—standing up on its edge, to the bed-plate.

The *electro-magnets* consist of circular cast-steel bars, secured at one end by bolting them upon the inner circumference of the field-frame; or they may be cast solidly with the field ring, and having fixed upon their inner ends pole tips built up of laminations of thin iron plates, these latter being so shaped as to extend further round the armature surface than the section of the bars, or *pole-pieces* as they are called, would do. A mass of iron or steel may be magnetised by passing a current of electricity through it, and will retain for a time some residual magnetism; the amount, and its permanence, being in accordance with the composition and degree of hardness of the metal. Very hard steel will retain its magnetism for so long as to be considered a permanent magnet, but it is, on account of its density, difficult to saturate. Therefore, for dynamo building purposes, the softest and purest qualities of iron or steel are selected, as being easily magnetised, and yet retaining so much *residual magnetism* as is required for starting the induction of currents in its conductors when the armature begins to revolve.

The strength or *density of magnetic flux* across the pole faces or *field* of weak magnets of soft iron, such as these pole-pieces, can be very much increased by passing electric currents around their surface. With this object, copper wires, themselves lightly insulated, are wound around them; the pole-pieces and their windings then forming *electro-magnets.*

Each electro-magnet will possess a field along its length, and its extremities will have the qualities of N. and S. poles. But as the strongest field is required at one end, two of the magnets are fastened endways inside the field frame. The polarity of their inner ends depends upon the direction of the current in their windings, and, as it is required that the inner end of the one shall be a N. and the other a S. pole, two pole-pieces with windings of differing direction are selected, and thus, with a section of the field ring joining them, a horse-shoe magnet is formed, with its strongest points presented to the revolving armature. This will be understood by a consideration of Fig. 171, showing the form and manner of winding of the pole-pieces, and their disposition in the field ring.

Although the turns and successive layers of copper wire forming the windings of the magnets only require to be lightly insulated from each other, it is highly important that they, forming a part of the electrical system, should be strongly insulated from the magnetic system. The engineer having to do with dynamos must take special care to test this by proper instruments, and these tests should be verified and checked from time to time after the machines have been installed. Any inherent weakness or deterioration of this insulation will inevitably result in break-down, and ultimately the coils will "burn out" and have to be rewound, an expensive job, to say nothing of the loss and inconvenience caused by stoppage of the dynamo whilst repairs are being made. When first built, both magnet and armature windings should have their insulation resistance between windings and their cores tested, by a pressure of at least 2,000 volts, alternating current, applied for five minutes.

The *magnetic field* is represented theoretically as consisting of a number of "lines of mag-

netic force" passing through the air from N. to S. poles. The strength of this field is measured as the *flux density* or number of magnetic lines in each square inch sectional area of the field of force, the field area being equal to that of one pole face. Thus the flux density is spoken of as being a given number of lines passing per square inch, and this density depends upon the amount of current measured in ampères and the number of turns it takes around the pole-pieces, by reason of the length of the copper conductors. In this way it is found that a given value of ampères x turns will produce on a certain section of core a flux density of resultant lines per square inch. Upon this basis a formula for the magnet design is constructed, and very exact results obtained.

The field magnets must be magnetised before any current can be produced by the dynamo. Their magnetisation is effected by passing a current of electricity through their windings, and so long as this current is passing they are said to be *excited*. Immediately this excitation ceases they become demagnetised, excepting for a small proportion of residual magnetism, varying in amount according to the qualities of the iron or steel of which they are composed. The harder the material of the magnet pole-pieces the more residual magnetism is retained, but on the other hand the more power will there be wasted in the effort of exciting them, and overcoming their *magnetic inertia*. Therefore iron is selected of such a quality as will retain just sufficient residual magnetism to start the field induction when the armature commences to revolve.

In the case of an alternating current dynamo, the exciting current is usually supplied from an outside source. Frequently a small continuous current dynamo is built on or connected to the alternator shaft, each machine having its own exciter for supplying its own magnets. A direct current dynamo, however, starts on its residual magnetism, and its full field strength is *built up* and maintained by the use of a small proportion of the current generated in its own armature, the dynamo being said to be *self-exciting*.

Two methods of exciting the field magnets are most commonly used, shunt winding, and compound winding of their coils. For the first method the pole-pieces are wound with a large number of turns of fine wire, and a small current is *shunted* through this winding to produce the requisite number of magnetic lines. As has been noted, a fixed number of lines are required in a given machine, and this number being relative to the product of ampères x turns, or *ampère turns*, may be obtained by using a large number of turns and small current, as in *shunt winding*, or by sending the whole current of the dynamo a few turns round the magnets, as in *series winding*. Or again, a combination of the two methods may be adopted as when *compound winding* is used. Either of these systems will give to the machine special characteristics, so that the method most suitable for its special work is adopted in designing the dynamo, whether incandescent or arc lighting, electric power or a mixed load, as the case may be.

The Armature.—The field magnet system being thus constructed, the moving conductors have to be introduced within the field of magnetic lines of force to afford the magnetism a path from N. to S. poles of less dielectric strength than the air between them, by closing the space with iron. This is effected by the revolving member called the *armature*. This consists of a cylindrical iron *core*, Fig. 171, 4, built upon a shaft, 1, revolving in suitable bearings, and carrying embedded in its outer surface the copper conductors which are to cut through the magnetic lines of the field, and by so doing have induced in themselves the currents of electricity generated by the dynamo.

The core is built up of a large number of thin discs of iron, insulated from each other and held together by an iron frame or *spider*, through which the shaft driving the whole is passed. In this way a cylinder or drum is formed, which not only acts as the closure for the field magnets, but, by reason of the currents induced in the conductors it carries, becomes in itself a magnet, having N. and S. poles at right angles to the field magnets, and producing in its own mass *Eddy* or *Foucault* currents. These currents are useless in themselves, and cause heating of the armature core. To prevent as far as possible their formation, the core as

noted is built up of separate insulated discs, and ventilation is provided by the introduction of skeleton plates forming air ducts, and producing a cooling effect by the forced circulation of air through its internal surfaces when the armature revolves.

In the outer surface of the armature core slots are cut in the direction of its length. These slots are lined with insulating material, and within them there are laid, level with the surface, the copper conductors called *armature coils* or *armature bars*. The coils consist of lengths of insulated copper wires, bent to a suitable shape, so that when laid in the slots one-half will lie with its end emerging from

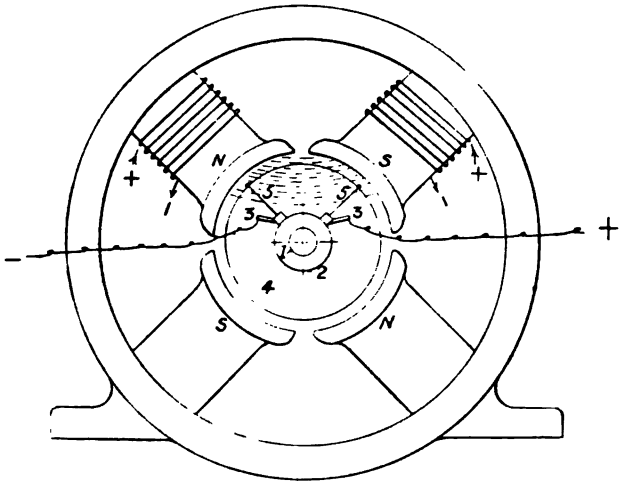


Fig. 171.—Winding of Pole-Pieces in Dynamo.

that slot which shall lie across the centre of a N. pole, when the slot carrying the other half will produce the other end across the centre of a S. pole.

Looking at the diagram (Fig. 171), it will be seen that the one armature coil shown, lies in this position, 5.

The space between the surface of the armature and the faces of the magnet poles is the *air gap*. Whilst it is, of course, necessary to have some clearance for the revolving armature, this gap, being the part of the magnetic circuit which offers the highest resistance to the passing of magnetic lines, is always kept as small as possible. The armature must be placed exactly central, and should its bearings, by wear, tend to lower it, and so make the gap unequal at top and bottom, they will require readjustment, in order that the air gap may be exactly equal all round the circumference of the armature.

Taking the dynamo as in the figure, with the coils wound to produce N. and S. poles, and one coil only on the armature core, it will be seen that the magnetic system consists of a ring or loop, including a section of the frame ring, the pole-piece N., the air gap, a portion of the armature core, and the pole-piece S.

When the armature is at rest, no magnetic lines are present in the air gap, save for those due to the small residual magnetism. The electrical system consists of the wires wound around the magnets, and those placed in the slots of the armature core. If we now take the ends of the two magnet windings marked − +, connect them together, and then connect the ends + − to, say, a strong battery of cells, or another dynamo, and send a strong current round the pole-pieces, we shall very much increase their magnetic strength, and have passing through the air gap N. to core, and from core through air gap to S., a large number of lines.

So long as the armature remains stationary, however, we shall have no electric currents in its conductor. But immediately it begins to revolve, the conductor *cuts the magnetic lines*, and a current is produced in it by induction.

This current will be proportionate in strength to the flux density per square inch, the number, and speed of revolution of such coils. By using heavy wires for these coils we can take heavy currents from the dynamo if we keep up a strong magnetic field, by providing a sufficient number of ampère turns on magnets and armature. By *armature ampère turns* is meant the number of times the current in the armature winding is made to pass round its section of the armature core, the sectional area of the wires limiting the number of ampères they will carry without overheating. This is measured in ampère capacity per square inch sectional area, and is written as *current density*, vary-

ing in value with the material of which the wire is composed.

Copper wires for armature windings are usually worked up to a density of 1,500 to 2,000 ampères per square inch, but this may vary considerably according to the ventilation and cooling of the core arranged for. It should not in any case exceed a limit which will cause the temperature of the windings to rise more than 60° Fahr. above the temperature of the atmosphere, when the dynamo has been giving the full number of ampères for which it is designed through a continuous run of six hours. The temperature rise which will occur can be exactly calculated beforehand in designing the dynamo. The armature coil in the figure is at the strongest point of the field. In its revolution the current induced in it will be in an opposite direction to that passing in the magnet coils. Thus at a S. pole the armature current will be + and at a N. pole −.

In its revolution the current induced in the conductor is at its greatest value when it arrives at the centre of the pole face. Having passed that point, it grows weaker until it arrives midway between the N. and the succeeding S. pole, and at this *neutral point* fails altogether. Passing this point, current is again induced, but the conductor being now in a S. pole, it is induced in an *opposite* direction. Thus in a multipolar dynamo the armature current will change its direction several times in each revolution. It is, therefore, an *alternating current*. Its alternations per second, or cycles, called its *periodicity*, are represented by the product of the number of pairs of poles multiplied by the revolutions per second of the armature.

During the revolution, therefore, a number of ampères at a definite voltage and with a definite periodicity will have been induced or *generated*. By adding to the number of conductors, and connecting them in series, we can add together their voltage and so obtain a higher pressure, proportionate to the number held in the section of the armature covered by one pair of poles, the speed of r.p.m., and the ampères of each section × the number of pairs of poles.

The product of these two values gives us the *kilowatts capacity* or *output* of the dynamo. The kilowatts ÷ ·746 = the *electrical horse power* given out, and this, say, + 5 per cent. = the HP. or mechanical energy absorbed by the effort of moving the conductors to cut through the magnetic lines of force in the air gap.

We may now take two copper or phosphor-bronze rings and thread them upon, but insulating them from, the shaft, and take also one end of each armature coil in each section so as to have all the coils which at any moment will be +, connect them to one ring and all the − ends to the other ring. Then by means of a fixed metal "collecting brush," adjusted to press lightly upon the revolving rings, we may collect the alternating current generated by the dynamo, and by cables attached to the brushes lead it away to the terminals of the machine for distribution. (*See* **Distribution Board.**) Upon these principles are built the "alternating current generators," and although modifications may be made (for instance we may keep the armature fixed, and rotate the field), all dynamo-electric machines work upon the same principle of induction between magnetic poles and moving conductors, or between fixed conductors and moving poles.

If we require that the dynamo shall give current flowing always in one direction, that is *direct* or *continuous current*, this must be done by *commutation*.

The Commutator.—This is built up of a number of short copper bars or sections, practically a collector cut across its width into as many sections as required. These sections are so attached as to revolve with the shaft, but are insulated from it by an insulating sleeve, Fig. 171, 2, and from each other by thin slips of mica. The two ends of each armature coil are then connected to two sections which (in a four-polar dynamo) lie at right angles to each other, and the armature connections are so arranged as to give at these four points a pressure in volts or an *electro-motive force* amounting to the added pressures of all the conductors.

Thus two bars opposite the two N. poles are −, and two opposite the two S. poles +, with the full pressure across them flowing in any conducting path which may complete the circuit. At the two + points are fixed brushes with cables attached leading to the + terminal, and

at the – points brushes connected to the – terminal, Fig. 171, 3. As the armature revolves, successive bars arrive at the strongest part of the field, and their induced currents then being at maximum value are collected by the brushes and carried away to the terminals.

Brushes.—These collectors are *carbon brushes* fitted in suitable holders, and a sufficient number are mounted together in a row so as to extend across the whole width of the commutator, and are kept in contact with its surface by springs giving a pressure of 1½ lb. per brush. They should, if properly fitted to the radius of the commutator, run for a long time with very little wear, all the attention required being that the commutator be kept clean and free from dust. Emery cloth should never be used, but if any roughness appear, glass paper held to the surface whilst running should keep the commutator smoothed. Usually, a *linen* cloth slightly moistened with benzoline will effect all the cleaning required. If the brushes *chatter* something is loose in their holders, or the commutator is rough. When the brushes are new, to heat them in a Bunsen flame to dull red and dip them in machine oil will ensure smooth and quiet running; but oil must never be used on the commutator, it must be simply kept free from dirt and carbon dust. A commutator does not require a lot of attention, if the brushes are properly fitted to start with, and the armature is running truly and steadily.

The dynamo has been described as having its fields excited from an outside source, and this would be necessary for an alternator generator, unless it were an "induction alternator."

But a continuous current dynamo may be made *self-exciting*, as at first the residual magnetism will start the induction, and the field can then be brought to, and kept at, full strength by sending a portion or the whole of the armature current round its coils.

Booster.—A "motor-dynamo" used to maintain or increase the pressure on long feeders, or in charging storage-batteries. A shunt-wound motor is coupled to a shunt or compound-wound dynamo, whose armature is in series with the circuit to be boosted. The voltage generated by the booster-dynamo is thus added to that of the supply mains, raising the pressure of the local circuit as required.

Moving Field Dynamo.—In this machine a small C.C. dynamo mounted on the end of the shaft is the exciter, and supplies the continuous low tension excitation current to the field coils by collector rings fitted on the shaft. The alternating current is generated in the stationary armature windings in the inside of the case, so that in this type of generator we have a fixed conductor having currents induced in it by a rotating magnetic field, instead of the reverse, as in other types of alternating and in all continuous current dynamos.

The illustration, Fig. 172, Plate XI., shows the field magnet frame of a direct current, 6 pole, 600 K.W. Westinghouse generator. This view gives a good idea of the manner of winding the field coils and placing them upon the cast-steel cores, the bolts securing which may also be observed. The coils are held in position by the extended laminated pole tips, which are bored out after fixing to suit the diameter of the armature, leaving equal clearance (air gap) all around its circumference. To the right is also shown a smaller complete dynamo with its armature and brush gear fitted.

Fig. 173, Plate XI., shows the armature core, slotted ready to receive the former-wound armature coils. These latter are shaped as shown at the right-hand (engine) end for compact disposal on the spider; the ends of the several windings embodied in each coil may be seen bared ready for connecting to the commutator sections.

Fig. 174, Plate XI., indicates a further stage; the whole of the coils are fitted, and are being connected up to the commutator. The large number of the commutator sections, each insulated from the others, are clearly seen, and a good idea of the size of the armature of a 600 K.W. traction generator may be gained from this illustration.

Fig. 175, Plate XI., represents 6 pole, 200 K.W. C.C. generators constructed by Messrs Dick, Kerr, & Co. for direct coupling to vertical enclosed engines, and are examples of modern types as designed for traction and the supply of power for large factories and engineering works.

Dynamometer.—A dynamometer is liter-



Fig. 151.—Internal View.

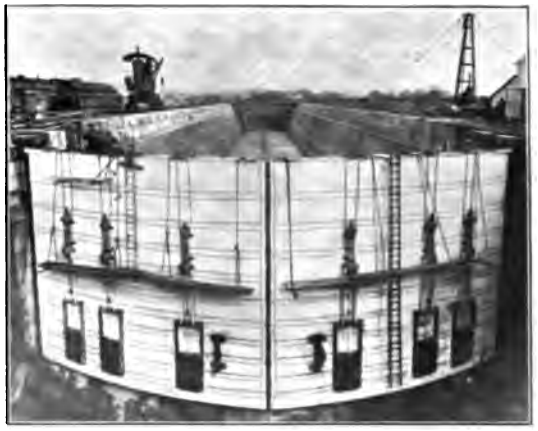


Fig. 152.—External View.

GATES AT THE UNION DRY DOCK, NEWPORT, MON. (The Thames Iron Works, Shipbuilding & Engineering Co., Ltd.)

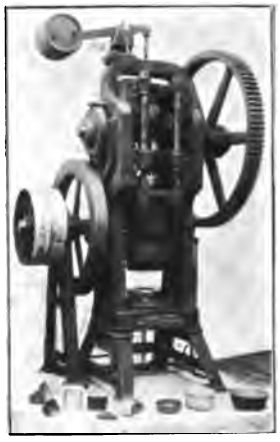


Fig. 158.—DRAWING PRESS. (J. Rhodes & Sons, Ltd.)



Fig. 172.—FIELD MAGNET FRAME OF 6-POLE WESTINGHOUSE GENERATOR.

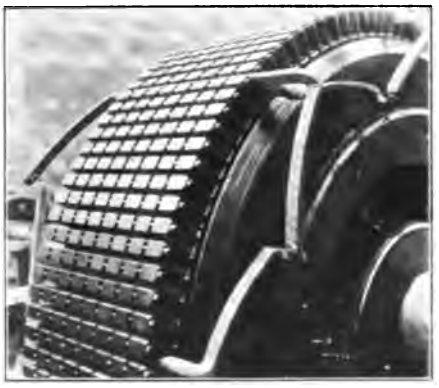


Fig. 173.—ARMATURE CORE OF WESTINGHOUSE GENERATOR.



Fig. 174.—BUILDING UP ARMATURE.

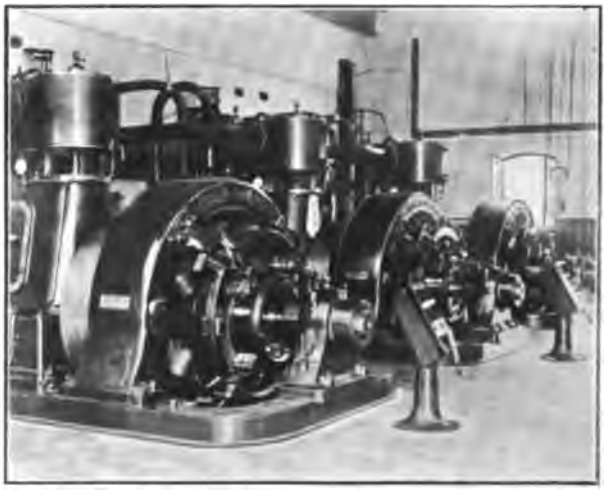


Fig. 175.—DIRECT-CONNECTED DYNAMOS. 400 revs. per minute.

To face page 176.

ally a measurer of power. In its broad sense it includes the steam engine indicator (*see* **Indicator**), and it includes the water, and other brakes, which, however, waste the power they indicate, though they may be used to illustrate the principle. Thus a rope brake is made up of one or more ropes in parallel attached to some fixed point by a spring balance, and partially encircling the driving pulley or flywheel of an engine. At the loose end of the rope band is a larger spring balance, or a scale pan. Such a brake will give the power of the engine by the following formula :—

$P = 2\pi r N(W - w) \div 33{,}000$, where P = horse power, N = revolutions per minute; $\pi = 3{\cdot}1416$; r = radius measured to centre of rope on wheel; W = weight on scale pan; w = reading of fixed point spring balance. The wheel rotates in the sense of lifting W.

In a water brake a series of blades on an axis revolve inside a casing, also fitted with blades to check water movement. The casing has a long projecting arm which rests on the table of a weighing machine. In the above formula, then, r = radius to point of rest of arm on scales, and $(W - w)$ becomes simply the reading of the scales.

Where the dynamometer must not absorb any power it is made in a different form. Thus the drawbar of a locomotive may consist of a coiled or flat spring so arranged with an index as to indicate the pull of the engine, the horse power of which exerted through the dynamometer is $P = SV \div 33{,}000$, where S is the pull in pounds and V is the velocity in feet per minute. Surging of the drawbar spring can be checked by the use of a dash pot, which, while allowing the full stress to come upon the spring, has a very small orifice, so that the oil or other liquid cannot be quickly transferred from side to side of the piston.

An hydraulic dynamometer may be arranged with a pressure gauge, to show the pressure in a cylinder the piston of which takes the pull. Any leakage may be made good by a small pump, and any surplus is allowed to escape by a hole which the piston uncovers if pushed too far back. The pull S is measured by the area of the piston multiplied by the gauge pressure. There is no serious inaccuracy from the friction of the cup leather, but where this is feared, the piston may be caused to rotate by specially arranged gears, thus eliminating all friction effects. The power in a running shaft may be measured by inserting in the length of the shaft a Houldsworth differential gear, consisting of a bevel wheel on the separated parts of the shaft, geared together by a pair of bevel wheels on a bar fixed in an outer casing. The torque of the shaft may be weighed by a lever exactly as with the water brake, and in the formula, r, and $(W - w)$ are to be similarly treated.

Dyne.—The C.G.S. unit of force, representing the force imparting in one second a velocity of 1 centimetre per second to a mass of 1 gramme.

E

Ear.—A lug, or snug, as it is variously termed. A flat extension standing out from a main portion to form a means of attachment.

Early Cut-Off.—The shutting off of steam from an engine cylinder working expansively, at a period usually less than at half stroke.

Earth.—A defect in the insulation of any part of an electrical circuit, allowing the conductor to come into contact with a conducting path directly connected with the ground.

Earthing.—If one conductor of an electric circuit be in contact with earth, and the other conductor, of opposite polarity, also becomes earthed, a current will flow in the conducting path thus established. In a three-wire system the neutral conductor is intentionally connected by a path of low resistance to earth. Should an earth contact then by accident occur on either of the two + conductors, and the contact be good, sufficient current may flow through it to form a short circuit, and blow the + fuse, or open the circuit breaker. As it is impossible on an extensive system to obtain perfect insulation, there is always some *leakage current* flowing, and this can be measured and recorded, and so form an indication of the insulation of the system.

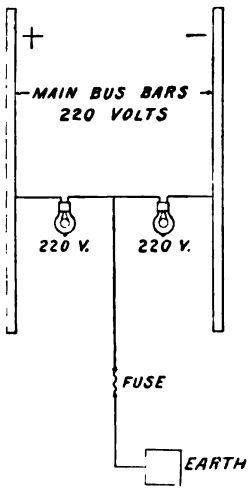


Fig. 176.—Connection with Earth Lamp.

On any installation the engineer will find it most useful to have an indication of the insulation of the various circuits. Instruments are made for the purpose, but an excellent method, by means of which faults can be indicated and located is shown in Fig. 176.

Glow lamps, each rated at the *full* voltage of the mains, are connected in *series*, so that only half the voltage is across each lamp. The centre of the wire is connected through a fuse to earth. Normally the two lamps will be dull. But should, say, the + lamp become fully incandescent and the other go out, this shows that a fault exists somewhere on the − side, whilst should the − lamp brighten the fault is on the +. Thus a sudden insulation failure is shown, or only a slight fault will cause a difference in the brightness of the two lamps, and will be on the side of the duller one. By opening the switches of the different circuits the fault can then be located and repaired before becoming so bad as to cause a breakdown of the whole system.

Earth Return.—If the + pole of a source of electricity be connected to an earthed conductor, and the − pole becomes earthed, current will flow from + along the conductor and return to − through the earth. In so returning it will choose the path of least resistance, so that in passing through earth it may take as its path either the ground or any conducting substance in contact therewith. Thus the current in a telephone circuit, with the battery − earthed, and the + passing through the instrument, and then earthed to a buried water pipe, will return through the pipe. But were the + and − simply buried in the ground, and no pipe near, the current would return through the ground, although it would be weakened by the higher resistance of its path. Thus, also, the rails of a tramway are used as a return. If laid in the ground with their ends separated or only in partial contact, the current would pass. But if made electrically continuous by bonding, the resistance of the return path is less, and so less power is wasted in overcoming it.

Earths—Weight of.—The following are the weights in lb. per cubic foot of the principa kinds of earth:—Rubble filling, 100; coarse dry sand, 100; damp river sand, 218; gravel, 90 to 95; mud, 102; common earth, 100; loam, 125; clay, 120 to 135; chalk, 117 to 174.

Earth Works.—Such works unsupported

by retaining walls depend for their stability on their natural angle of slope, or angle of repose. Tables given by different observers have but a limited value, because of the effects of dryness and of moisture. Increase of the latter diminishes frictional resistance, and almost entirely nullifies the values given for dry materials, hence the reason of landslips. Angles of repose for different substances are: dry sand, from 21° to 37°; gravel and shingle, 35° to 48°; clay, 40° to 45°; various earths, 28° to 55°.

Ebonite.—A material composed of india-rubber and sulphur, and possessing in a high degree the properties of an electrical insulator. Ebonite is very hard, and can be highly polished, in which state its surface is non-hygroscopic; it can be drilled and tapped, and is much used for electrical insulation purposes.

Eccentric.—The agent by which the slide valves of engines are reciprocated, and through which the direction of motion of the engines is reversed. An eccentric is in principle a crank. Its *throw* is the distance between the centre of the crank shaft, and the centre of the sheave or body. The *sheave* is keyed on the shaft, excepting in the unusual shifting type, and it rotates within the *straps*, which are checked or registered thereto to prevent lateral slip. Small eccentric sheaves are made solid, and of cast iron, larger ones are lightened by piercing them with holes. Sheaves are, when practicable, fitted over the ends of their shafts and keyed on. Often, however, they must be cast in two pieces, to fit between cranks, one piece being necessarily much smaller than the other. The smaller piece is then generally a forging. The straps are of cast iron, lined with gun-metal, or with a white metal. Or in small eccentrics, gun-metal is used for the entire straps. Straps are of course necessarily made in halves, and bolted together. Lugs are kept as closely in as possible, and are of good thickness. To one-half the strap the *eccentric rod* is attached in various fashions, and a lubricator is provided in it. For reversing by link motion the two sheaves are generally cast together.

Eccentric Gears.—Toothed gears of various kinds have their shafts set eccentrically in order to produce variable rates of motion. Some of these are more curious than useful. They include the following:—Crown gears with pin teeth driven by a long pinion. The shaft of the crown gear being set eccentrically, it is driven at rates varying with the radius of the teeth. Elliptic gears simply, with shafts set in one focus, and having provision for keeping the teeth in engagement; used for quick return. Elliptic gears in combination with spur gears to produce quick return. Scroll gears, in which the pitch line is of volute shape, and therefore the motion increases from minima to maxima. A scroll bevel wheel, driving an ordinary bevel pinion, with provision for keeping it in gear from minima to maxima.

Eccentric Loading.—Relates to the effect of a load on a horizontal girder connected to a vertical stancheon or beam, without any similar counterbalancing load at the opposite side. Such a load always stresses the stancheon or beam more severely than the horizontal girder is stressed, and of course it increases with increase in the breadth of the vertical member, which lengthens the distance at which the loading operates. The following method of dealing with this problem is due to Messrs Hall & Pickles. Its object is to find the load acting down the centre of the stancheon, which would strain its members to the same extent. The formula, however, involves the use of an "eccentricity factor," which is based on calculations by the firm, and embodied in their tables of steel sections of different sizes. But having these factors at hand, the labour of calculation is simplified. The method in brief is this:—

A girder connected to the flange of a vertical joist or stancheon tends to cause bending about the axis of the latter. Assume a load on the girder of 30 tons, acting at the joint. Then 30 tons × eccentricity = 5 in. × eccentric reduction factor for the axis, given in the section tables by the firm, + 1. These factors are given for all joists from 3 in. × 1½ in. to 24 in. × 7½ in., and for both axes; that through the web and that transversely thereto.

Thus, taking a section 10 in. × 6 in., the eccentric reduction factor of which is ·292.

30 tons [(5 in. × ·292) + 1 =
30 (1·46 + 1)] = 73·8 tons.

So that the joist will support an axial load of 73·8 tons as safely as a flange load of 30 tons.

A similar method is adopted for beams of box section.

Economiser.—An apparatus for utilising the waste heat from steam boilers in its passage from the brick-work flues to the chimney. It shows to best advantage when there is a battery of Lancashire boilers connected with one main flue in which the economiser is located. Essentially it comprises a nest of cast-iron pipes, set vertically, through which the boiler feed water is forced by pump or injector, and is heated by the waste gases up to from 90° to 300° Fahr.

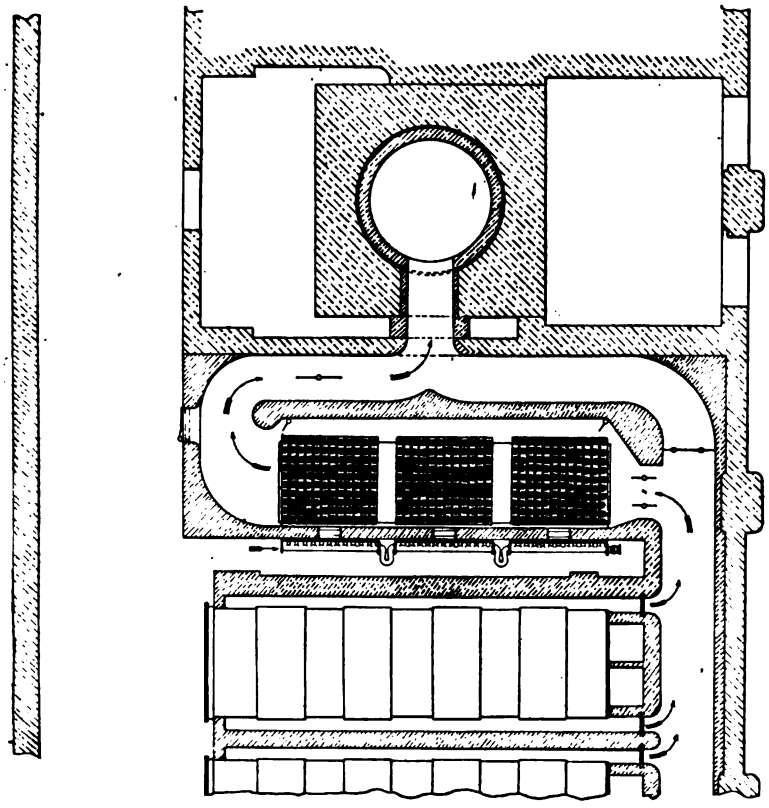


Fig. 177.—Plan of Green's Economiser, Liverpool Power Station.

It is a remarkable fact that much more attention has been given to the economical use of steam in the engine than to its economical generation in the boiler. Yet in the latter the escape of heat by the chimney, due either to imperfect combustion, or to the neglect to use it to heat the feed water, causes excessive heat losses. Chimney gases must leave at a temperature much higher than the steam. *See* **Boiler Efficiency**. As pressures increase, so do the temperatures of the gases. It is therefore more than ever necessary to utilise the waste gases, and reduce fuel consumption by heating the feed water with them. The difference in temperature of the gases on entering and leaving the flues represents the heat gain, besides which a large reserve of hot water is available, and the hot feed prevents damage to the boiler that results from introduction of cold feed water.

The construction of Green's Economiser, four installations of which are shown in Figs. 177-180, is in brief as follows:—It consists of a series of cast-iron pipes (cast on end and tested hydraulically) $4\frac{9}{16}$ in. diameter, by 9 ft. in length. These are arranged in sections of various widths, placed across the main flue between the boilers and chimney. The sections are formed by forcing the turned ends of the tubes into horizontal top and bottom boxes by hydraulic pressure. They are connected by branch pipes. The feed water is forced into the economiser by a pump or injector at the lower branch pipe nearest the point of exit of the gases from the flues, emerging through the upper branch pipe at the opposite end from whence the gases enter. Provision is made by an automatic scraper with chilled edges, moved by rods and chains through gearing, and fitted to each pipe, for the removal of soot, which is a bad conductor of heat. The scrapers are actuated by belt or small independent engine. The interior of the pipes can be flushed with a water hose to prevent accumula-

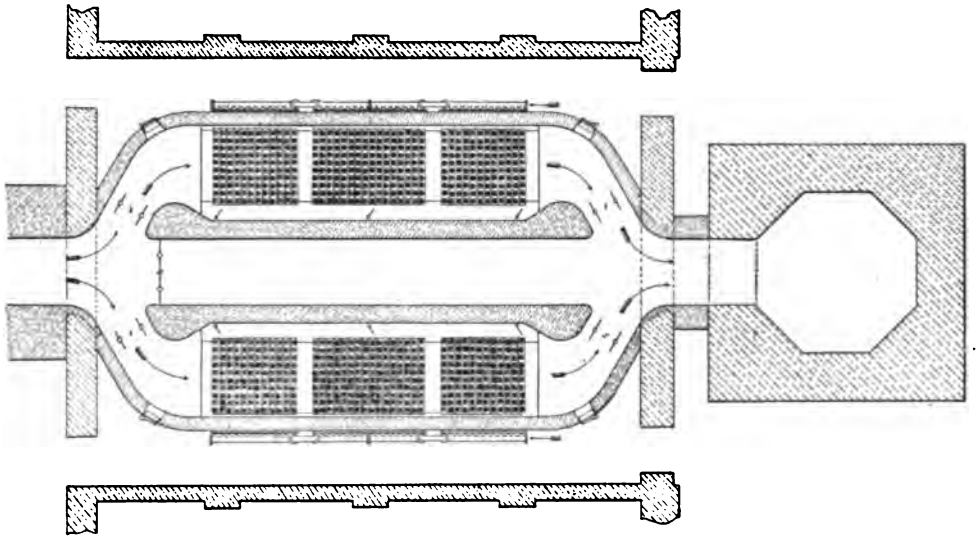


Fig. 178.—Plan of a Green's Economiser at Salford Corporation Electricity Works. 800 Tubes.

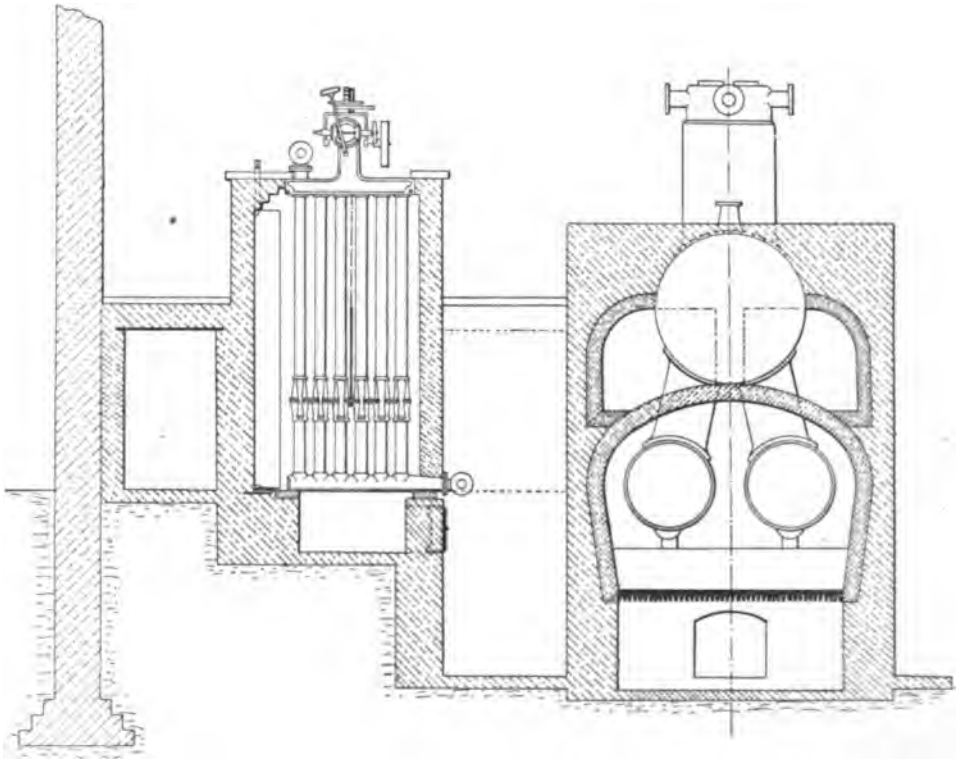


Fig. 179.—Vertical Elevation of a Green's Economiser fitted to Elephant Boiler.

tion of deposit. The pipes are arranged in groups of nearly a hundred each, with passages between to facilitate inspection.

Provision is made for the replacement of any tube due to accident. The lids are of several types to suit low and high pressures.

The rule given for the size of Green's Economisers is :—Take the quantity of water evaporated per hour in the boiler, and divide by $6\frac{1}{4}$, which is the capacity in gallons per tube of the economiser. Thus, if a boiler evaporates 600 gallons per hour, 600 divided by $6\frac{1}{4} = 96$ tubes. Another rule, if the evaporation is not known, is to allow four tubes for each ton of coal consumed per week. The number of tubes is increased by units of four sections. If an economiser is four tubes wide, it must be increased by 16 tubes; if six tubes wide, $6 \times 4 = 24$ tubes, &c.

The saving effected in fuel by the use of the economiser varies from 15 to 20 per cent. of the total fuel consumed. The temperature is reduced on an average from 650° Fahr. on the boiler side, to 350° Fahr. on the chimney side, and the temperature of the feed water is increased on an average about 200° Fahr.

Eddy Currents.—Internal currents generated in a magnetised armature core. *See* **Dynamo.**

Effective—Efficiency.—Used in a similar sense to *nett*. An effective section of a boiler is the nett section taken through the rivet holes. Effective heating surface is that which is available for steam raising. Efficiency is the ratio of capacity or work done to some standard, practical, or theoretical.

Egg-End Boiler, or **Hemispherical-ended Boiler.**—An old type which displaced the wagon boiler as being much stronger. It derived its name from the shape of the two ends, which are of hemispherical form, closing the cylindrical barrel. This is the strongest form possible, the completed sphere excepted, a hemispherical end being just twice as strong as the cylinder of equal diameter and thickness. The principle of maximum strength was also embodied in the old balloon boilers. But in both, other things of equal importance were overlooked. There is nothing gained by making ends twice as strong as the barrel, hence the substitution of cambered unstayed ends, and of flat stayed ends in later practice. But far more than that, there is the small amount of heating surface possessed by egg-ended boilers, which are externally fired, using a wheel draught in brick-work flues. Another objection equally fatal, is the risk of overheating due to deposit over the lower parts next

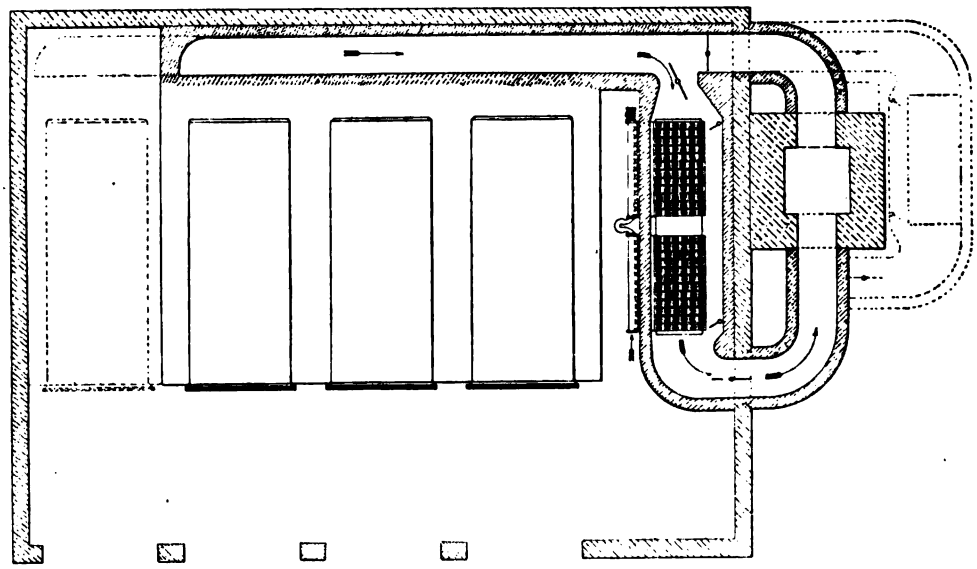


Fig. 180.—Plan of a Green's Economiser with provision for Additions to Plant.

the flames and hot gases. As a result of this, many explosions of these boilers have happened. When fracture occurs it is generally along the seams, at and near the bottom, and chiefly next the furnace. Fracture is due mostly to the presence of deposit on the bottom plates over the fire, aggravated in some cases by bringing cold feed water into the bottom of the boiler close to the heated plates. Grooving often occurs in these boilers close to the edges of the seams. In the internally fired group, deposits settle largely at the bottom of the shell, where they are less harmful than next the fire. Egg-end boilers will only carry low pressures, and their use is now principally confined to the older iron works, where they are fired with the waste gases from the puddling, and reheating furnaces.

Egg-Sleekers.—*See* **Moulders' Tools.**

Ejector.—*See* **Injector.**

Elastic Blow.—The opposite of a dead blow. *See* **Dead.**

Elastic Clutch.—A term applied specifically to the Snyer clutch, which is unique in its design. Engagement of the faces is effected without rigid claws, or rigid members of any kind; the place of which is taken by a number of brushes of flat steel wire standing out thickly from one face, engaging with a number of shallow toothed plates on the other. The particular feature of these is the absence of shock in starting up, hence they were at first used very much for dynamos when the practice of coupling dynamos to separate engines was the common practice. They are still employed for all kinds of loose coupling, as of shafts, gears, fast and loose pulleys, and are of especial value at high speeds of rotation, at which it is impossible to put claw clutches safely into gear. A case is cited of a clutch making 1,000 revolutions per minute, thrown in at full speed. The slipping capacity of the clutch permits it to be thrown in when engines are running at full speed, since the clutches slip, until they attain the engine speed. In case of any extra strain thrown on it, the slip becomes a safety valve, preventing fracture of some other element.

Fig. 181, Plate XII., shows the two clutch faces laid open. Fig. 182, Plate XII., shows a very large clutch, transmitting 500 HP., on a 9-in. shaft.

Elasticity.—In ordinary language this term is taken to mean the property by virtue of which a body regains its original shape or volume when the force which caused it to alter that shape ceases to act. In a more scientific sense elasticity is the *resistance* which matter offers to a change in shape or volume. The alteration either in the form or volume of a body is called a *strain;* the force producing the alteration is a *stress.* The force producing the strain may be a push (*compressive stress*) as in struts, or a pull (*tensile stress*) as in ties. The relation between stress and strain may be ascertained by means of an instrument called an "extensometer," increasing loads being gradually applied to bars, plates, &c. A change in length of $\frac{1}{50{,}000}$ of an inch can be observed in Ewing's extensometer. Such experiments show that the strain is proportional to the stress which produces it—equal increments of stress produce equal increments of strain. This is known as Hooke's Law.

This law is true, however, only within certain limits. Beyond a certain load the strain is not proportional to the stress, the stretch increasing faster than the load. The point at which the law ceases to hold good is called the *limit of elasticity*, or *elastic limit.* If the limit is passed, the bar, plate, wire, &c., no longer regains its original dimensions on the removal of the load, but remains permanently stretched. This is known as *permanent set.* For various reasons it is often difficult to decide the point at which the elastic limit of any material is reached. Hence in machines and structures it is necessary to allow a good margin to ensure that the stresses in any material should never cause the strain to reach or exceed the elastic limit. It is probable, too, that permanent set occurs to a slight extent before the limit of elasticity is reached.

Since the extension is proportional to the pull, it follows that for any body the ratio $\frac{\text{stress}}{\text{strain}}$ is constant, that is, until Hooke's Law breaks down, and the limit of elasticity is reached. The ratio $\frac{\text{stress per unit of area}}{\text{strain per unit of length}}$ is called the modulus of elasticity. (A "modu-

lus" is a constant multiplier to be used with some variable quantity; Lat. *modulus*, diminutive of *modus*, a measure.)

Elasticity—Modulus of.—*See* **Elasticity.**

Elastic Limit.—This corresponds with the load on a specimen or structure which does not cause permanent deformation, or permanent set; the object returning to its original shape on the removal of the load. It is therefore the load beyond which the stress and strain cease to be proportional, but in which the stresses increase more rapidly than the strains. The elastic limit corresponds nearly with what is termed the *yield point* (occurring a little within it) at which permanent set, crippling, and large deformations begin to occur.

The coefficient of direct elasticity (E) is termed *Young's modulus*. It is obtained by dividing the stress p per unit of area, by the extension e (or compression) per unit of length. Thus $E = \frac{p}{e}$.

The elastic limit, therefore, and not the ultimate strength is the important point to determine in estimating the strength of a material or structure. The capacity of returning to its original form after an infinite number of repetitions of stress is the essential property required (elastic set).

But the elastic limit may be raised artificially by repetitions of stress beyond the natural elastic limit. A familiar example is afforded by hammer hardening. It may also be raised by alloying a metal with another of a different atomic volume. These are well-known facts, the explanations offered of which would lead us too far afield; but it is held that the particles of a stressed material are polarised in the direction in which distortion takes place, and that the material tends to become depolarised by returning to its original form. Many of the molecules will be displaced permanently, and this corresponds with the elastic limit.

Much can be learned by plotting the behaviour of a bar under stress beyond the elastic limit. In Fig. 183 the horizontal lines represent stresses in tons per square inch, and the vertical lines strains or extensions in parts of an inch. In iron and steel a line drawn through the points which indicate stresses and their corresponding strains will be straight up to the yield point *a*. Then a sudden drop occurs in the resistance of the material. Extension in length and contraction of area increase rapidly. But the diagram shows that the strength of the material increases, as indicated by the ascent in the curve to the peak *c*. Then local extension follows until fracture occurs at *d* at a lower load than the sample had previously endured.

The diagram is drawn to too small a scale to record accurately the stress-strain lines at and just previous to the yield point. These are shown enlarged to the right for tension A and compression B. This shows that up to *a* the

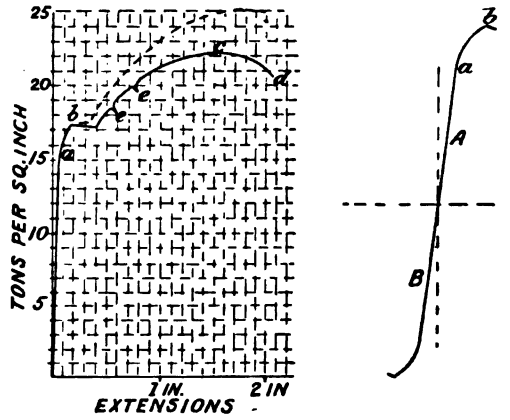


Fig. 183.—Stress-strain Diagram.

specimen acts as an elastic spring, but beyond that the deflection is rapid. Also that the lines are the same for extension and compression.

The stresses immediately previous to fracture are borne on reduced sections of the specimen, and are therefore more severe than the earlier ones, if reckoned per unit area.

Another point is illustrated here, namely, the effect of pauses in the impositions of stress. At every pause the bar recovers its strength, for on the re-imposition of the load the curve rises. Two such cessations are indicated at *e*, *e*.

Elastic Washer.—*See* **Lock Nut.**

Elbow.—*See* **Bend Pipes.**

Electrical Alarm.—Electrical apparatus so arranged that under certain conditions provided for, a signal is transmitted electrically to a place where it can be observed. Thus the

opening of a door or window may be made to complete the circuit of an electric bell, and cause it to ring. An automatic Thermo-Electric Fire Alarm is also employed. A strip of metal easily affected by heat, is so arranged that an increase of its temperature by a fire in its vicinity causes it by its expansion to make an electrical contact and transmit a signal to a distant station, or also to automatically set to work a local fire-extinguishing apparatus.

Electrical alarms can be arranged in many different ways, are simple, cheap, and reliable, and have often proved of great practical service.

Electrical Apparatus.—Any machinery, instruments, or appliances designed for use in electrical circuits.

Electrical Conductivity.—The opposite of electrical resistance. The capacity of a material for allowing the passage of currents of electricity, varying inversely as its specific resistance, according to its nature and composition.

With regard to copper, it is necessary to use the purest quality obtainable, since the presence of a minute quantity of an alloying metal greatly increases the resistance.

Electrical Distribution of Energy.—Whilst electricity cannot really be either generated or consumed, it can by the expenditure of mechanical or chemical energy be so treated that inequalities of pressure are produced. Its natural tendency to produce absolute equality of pressure in all portions of a charged body gives it the power of electromotive force. This force may be made to move in prescribed conducting paths, and is in reality the energy producing the inequality of pressure.

Thus the effort of overcoming the electrical resistance in its path is the expenditure and conversion of energy which can be effected in any part of the conductor.

In a lamp it is shown as heat and light, in a bell as magnetic attraction of an armature, in a motor as mechanical power, in an electrolytic cell as electro-chemical energy, &c.

Systems of conducting paths are constructed, and electricity is made the vehicle for transmitting, say, the mechanical energy of a steam or gas engine to any number of distant points, where its power as electro-dynamic force may be utilised and absorbed in various ways. The superiority of electrical transmission of energy over all other systems has been fully demonstrated. Distribution over large areas can easily be arranged to give an efficiency of 95 per cent., and the centralisation of power generating plant with all its attendant advantages, makes electricity the most economical, powerful, and efficient distributor of energy.

Electrical Engineering.—The application by the engineer of the science of electricity to the practical purposes of industries.

The electrician, studying the purely scientific and theoretical development of electrical research, has obtained a knowledge of electricity, which the practical engineer has applied to the requirements of his work, to such an extent, that there is at the present day hardly any branch of manufacturing industry into which the use of electricity in some form has not found an entry.

Electrical engineering, as a combination of engineering and electrical knowledge, and the application of science to practical work, has already effected wonderful results. There is a constantly expanding field of work, and innumerable openings and directions in which electricity will develop. For the man wishing to acquire a knowledge of electrical practice, there are now within reach of all so many facilities in the way of technical institutions, literature, &c.; and examples of the applications of electricity are so numerous, that in a short time it will be so usual and necessary for the practical engineer to be also learned in electrical matters, that mechanical and electrical engineering will become the one business of "engineering."

The various departments of the electrical engineer's and electrician's work are treated under separate headings, **Alternating Currents, Ammeter, Arc Lamps, Dynamo, Electricity, Electric Motors, Electrical Distribution of Energy, Electric Cables, Electric Driving, Electric Traction, Electric Lighting, Storage Batteries,** &c.

Electrical Work.— Electrical energy, measured in C.G.S. units, expressed in joules. The joule is equal to ·00134 HP. This

measure of electrical work is stated as the heating effect of a current passing in a conductor. *See* **Joule's Law.**

Electric Arc.—An electric discharge in air from a + to a − conductor. The arc of an arc lamp, induced by first bringing into contact the points of two carbon rods, and then withdrawing them a short distance, when the current will arc across the gap, to a distance proportionate to its E.M.F. This arc is formed of particles of carbon rendered incandescent by the current carried, and will be sustained so long as the carbon points are kept at a suitable distance apart. *See* **Arc Lamps.**

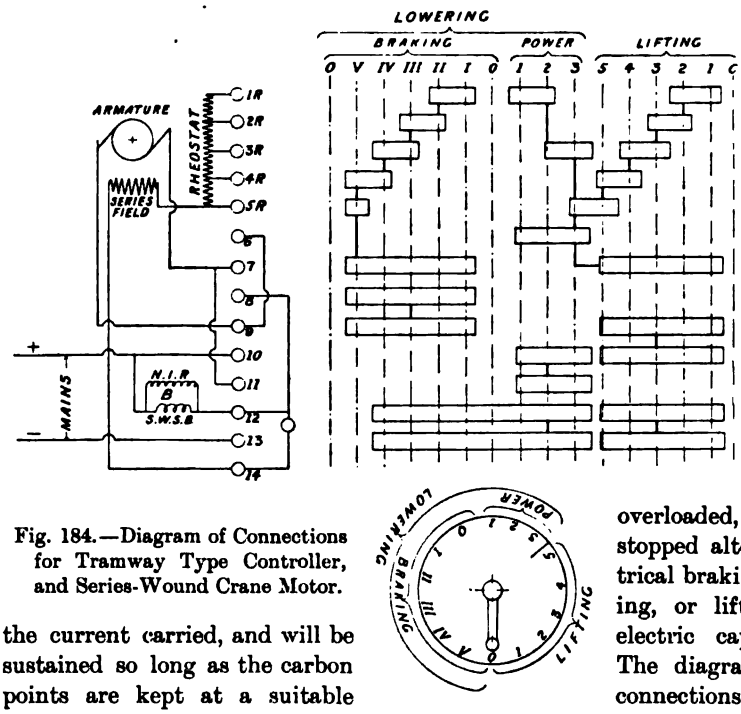


Fig. 184.—Diagram of Connections for Tramway Type Controller, and Series-Wound Crane Motor.

Electric Battery.—A primary source of electricity composed of a number of chemical cells. *See* **Batteries—Primary.**

Electric Brakes.—When the supply of current is cut off from an electric motor, the kinetic energy of the load drives the motor as a dynamo, and generates current which flows in the reverse direction, which current is absorbed by a special resistance placed in circuit with the motor armature. When running at the full speed for which it was designed, the motor generates current of an E.M.F. slightly below that of the mains. Below the speed of synchronism, that is the speed at which, if run as a generator, it would develop E.M.F. equal to that of the dynamo supplying the power, the motor is taking current from the mains, because of its lower E.M.F.

If, however, the load it is driving tends to overrun its proper speed, and itself to run the motor, at a speed above synchronism with the dynamo, the motor becomes a generator and will return current to the main circuit. In tramway systems, for instance, it can be so arranged that when a car is descending an incline, its motors may be allowed to run at more than normal speed, when they will generate power which is returned to the line and helps to drive other cars running on the same section.

Several systems of "*regenerative*" operation are in use, and considerable economies in power can thus be effected. On a long incline the motors may regenerate all the way down; or at any moment the current thus obtained may be diverted and absorbed by a resistance, until the motor is overloaded, and its speed reduced or it is stopped altogether. This method of electrical braking is also used on motors hauling, or lifting suspended loads, as in electric capstans, winches, cranes, &c. The diagrams, Figs. 184, 185, show the connections for a crane hoisting motor arranged to lift at five speeds, with three lowering by power, and five electric braking positions on the lowering side.

For the sake of clearness the "*tramway*" type of controller used is shown as having its revolving power-cylinder spread out flat, Fig. 184. Fig. 185 shows the same motor and controller, but by the dotted lines the current can be traced as coming *from* the motor, + terminal through the No. 1 brake position, and returning to the motor −. The descending load is now operating the motor as a generator, its current being absorbed by the whole of the rheostat. The speed of lowering can be regulated on any of the five braking positions. Thus, if it were

required to lower at a moderate speed, the controller handle would be brought first to No. 1 on the lowering side, and then back, say, to No. 3 brake position, and the load would descend at a medium speed to the ground. But suppose that it is required to lower quickly, and stop before the load reached the ground, then the handle is brought first to No. 3 lowering position, and to stop is put back to No. 1 brake; or again, if lowering on No. 3 braking position, a stop can be quickly made by moving to No. 1 brake. In this way the motor is under perfect control, and after being started in the lowering

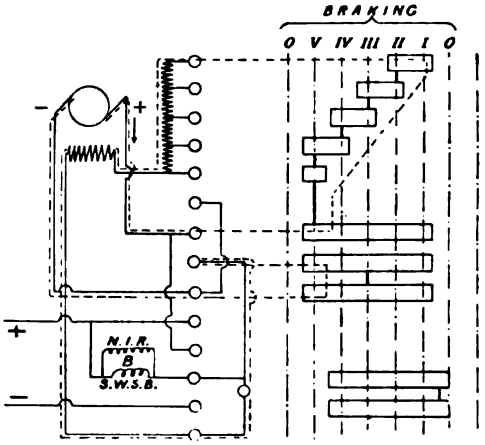


Fig. 185.—Controller Connection when Electric Braking is used.

direction on one of the power positions, no current need be taken from the mains for lowering, the load lowering itself at a speed controlled by the current taken from the regenerating motor.

Although here shown adapted to a series-wound crane-motor, electric braking can be used also for shunt, or compound wound motors. Regenerative control-returning current to the mains can be used for capstans, winches, or hauling gear lowering loads from a good height or down long inclines, where the power is supplied by a private generating plant. When the power is taken from public supply mains, however, it would have the effect of reversing the supply meter, and the authorities would probably object, in which case electric braking—that is, absorbing the regenerative current in a resistance—should be adopted.

Electric braking of alternating current induction motors is effected by counter-current, that is, by applying current from the mains in opposition to that generated by the motor when it is running at a speed above synchronism. The two currents, being out of phase, an extra amount of slip of the rotor is produced, and the motor can be quickly brought to rest.

In the electro-magnetic brake, employed on tramways, the current produced by the motors running as generators, in the way described previously, is passed round the coils of a magnet, combined with a track-shoe or slipper, which is powerfully attracted to the rails, so pressing on them and retarding the car.

Electric Bridge. — The "**Wheatstone Bridge**," an instrument for measuring electrical resistance by comparison with a known standard of ohmic resistance.

Electric Cables. — Electrical conductors formed of one, or a number of copper wires stranded together, covered with a dielectric of bitumen, indiarubber, paper, or other insulating material. The following typical specifications will serve to impart an idea of the building up of cables. In a plain sheathed type the strands of copper are covered with paper or spun jute fibre, afterwards impregnated with bitumen and oil blended for the purpose. The core is then covered with a solid tube of lead, made direct on the cable, by heavy hydraulic pressure. Or, after lead sheathing, an outer serving is put on, the cable being passed through a bath of preservative compound, and then served with jute yarn, or tape. Armoured cable is that in which the lead sheath (after a bath of compound) is protected by spirally winding steel tapes upon a bedding of yarn. The steel may be further covered by jute yarn. Interlocking segments of steel are alternatively employed, instead of wire or tape. Numerous changes on these methods are rung. In many cases rubber takes the place of the first coatings mentioned above.

The electrical carrying capacity of a cable depends upon the number and sectional area of its wires, and is based upon the heating effect of a current of 1,000 ampères per square inch of sectional area. Thus the current which may safely be transmitted by an insulated cable

without risk of damage to its insulation by overheating is fixed upon, whilst the safe pressure is limited by the dielectric strength of its covering or "insulation resistance measured in megohms." The efficiency of transmission depends upon its resistance, which causes a fall of potential, or "drop of voltage." The table shows the usual sizes of cables used.

ELECTRIC CABLES—SIZES, CAPACITY, AND RESISTANCE.

Size S.W.G.	Cross Sectional Area sq. in. of the Strand.	Current giving 2½ Volts Drop in 100 yds. Lead and Return.	Resistance per 100 yds in Ohms at 60° Fahr.
18	0·0018	1·8	1·38
3/22	0·0019	1·9	1·265
16	0·0030	3·2	0·736
7/22	0·0044	4·4	0·538
7/20	0·0072	7·2	0·329
7/18	0·0128	12·8	0·185
7/16	0·0229	22·9	0·1039
19/18	0·0349	34·9	0·0679
19/16	0·0624	62·4	0·0379
37/16	0·1219	122·0	0·0194

NOTE.—To find size of cable for a motor, add 10 per cent. to its rated B.H.P., multiply the result by 746 and divide by the voltage. This will give the current required, and the cable corresponding to this figure in column 3 will be suitable. Thus for 10 B.H.P. motor at 230 volts:

$$10 \text{ B.H.P.} + 10 \text{ per cent.} = \frac{11 \times 746}{230} = 31{\cdot}3 \text{ amps.}$$

For this, if the distance is under 50 yards, take 19/18 cable.

Electric Crab.—A crab driven by an electric motor. A typical example is shown in Fig. 186, Plate XII. The side frames and bedplate are constructed of steel plates and sections, the necessary bearings for the various shafts being riveted thereto; some of the gearing is machine cut. The barrel spur pinion is withdrawn by means of a lever; a brake is fitted to the barrel shaft and is operated by foot lever. The motor is series-wound and reversible, a suitable controller being provided. Hand gear is fitted, and forms a useful auxiliary when current is not available. The illustration is that of a fixed crab. For information about the travelling or trolley type of crab, *see* **Electric Traveller.**

Electric Crane.—All types of cranes can be driven electrically, and with any class of electric current. They may have their various motions fitted with separate motors, or they may have all motions driven from a single motor. Current is supplied to fixed cranes by means of cables, usually led through the foundations and up through the centre pivot, where *collecting rings* connect to the revolving portion. Portable cranes collect current in various ways; small portable cranes usually have trolley poles connecting to overhead wires; harbour portal cranes have flexible cable connections to plug boxes which are fixed at intervals along the quay; some cranes are fitted with ploughs to collect from a conduit or from live rails.

Electric cranes and travellers have occasioned the development of a special type of motor, due to the intermittent and fluctuating character of the load. As it is difficult to settle the right size of motor or suitable temperature test for different classes of cranes, some manufacturers have special ratings which give outputs under different conditions of intermittent workings or load factors, so that if the times and durations of the cycle of operations in lifting, slewing, &c., are known, a motor can be selected suitable for that rating. Messrs Siemens Bros. & Co., Ltd., give the following ratings, five to each motor:—

(*a*) For 1½ minutes out of every 12 minutes.
(*b*) „ 2 „ „ „ „
(*c*) „ 3 „ „ „ „
(*d*) „ 4 „ „ „ „
(*e*) „ 6 „ „ „ „

Fig. 187, Plate XII., illustrates a single motor portable crane collecting from overhead wire. The arrangement of gearing is very similar to that of a steam crane, but in place of boiler and engines a motor is geared to drive the shaft which corresponds to the crankshaft of the steam crane. A suitable controller enables the motor to start, stop, and reverse in a similar manner to a steam engine.

Fig. 188, Plate XII., shows a multi-motor crane taking current by a flexible cable, and



Fig. 181.—Elastic Clutch.



Fig. 182.—Elastic Clutch Transmitting 500 HP.
(Cowlishaw, Walker, & Co., Ltd.)

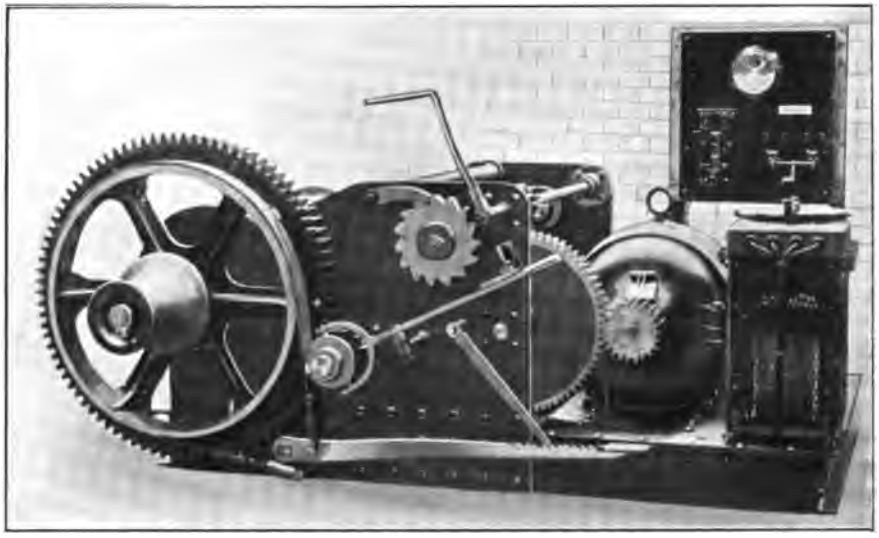


Fig. 186.—Electric Crab, with Auxiliary Hand Gear. (Jessop & Appleby Bros., Ltd.)

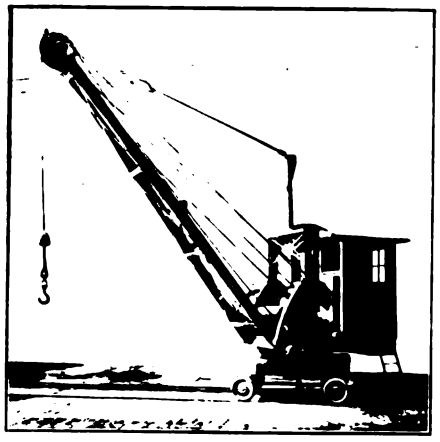


Fig. 187.—Single-Motor Electric Crane, Lifting 3 Tons at 16 Ft. Radius.
(Jessop & Appleby Bros., Ltd.)



Fig. 188.—2-Ton Three-Motor Electric Crane.
(Thomas Smith & Sons.)

To face page 188.

which is usually placed between, or sometimes at the side of the rails. There is one motor for hoisting and travelling, one for derricking, and another for slewing. An electro-magnetic brake is fitted to the hoisting gear, which automatically takes charge of the load when current is cut off.

Various devices are fitted to electric cranes, such as *limit switches*, which operate at the limit of a particular movement, and automatically cut off the current supply; *slipping clutches* which permit movement between a particular gear and its shaft should a heavy load be suddenly imposed, and so prevent breakage of gear, &c. Electric cranes are also dealt with under their various types.

Electric Currents. — The movement or "flow" of electricity in a conductor caused by the tendency to equalise differences of potential created at its extremities. The magnitude of a current flowing at any moment is measured in ampères. Ampères × time give ampère hours; this × the voltage and ÷ 1,000 equals the kilowatt hours (or B.T.U.) passed in the given time. The work done in an electric circuit depends upon the current flowing. The power of an electric current is measured by the production of a heating, magnetic, or chemical effect observed from the flow in ampères.

Electric Driving.—The electric motor is a more efficient machine at variable loads than the steam or gas engine, and is self-governing. The electric transmission of power renders possible the centralisation of the whole power-generating plant. The use of numerous small units of boilers and engines, long lengths of steam piping and shafting, gearing, belts, and other power-consuming details is done away with. Having produced the power, its transmission to the places where it is required for use can be best effected by electricity, which by means of suitable cables can distribute it over any required area in a very efficient manner. The cables and the motors they supply are practically independent of conditions and situation.

The cables, if properly designed and installed, do not deteriorate or wear out with use. The life of a cable is the life of its insulation, but even should this be damaged or destroyed the copper of the cable is not affected, and can be used for an indefinite time.

The electric motor can be put anywhere; it can be taken direct to the work it has to do, or may be portable, can be fixed in any position, and does not require heavy foundations. The machinery to be driven can therefore be located in the best positions to suit the work, and need not be tied to lines of shafting, gearing, &c.

For the operation of machines in factories of all kinds, or the machine tools, &c., in engineering workshops, the electric motor may be used either to drive groups of machines of small power, or be coupled direct to larger or isolated machines.

Motors can be built from $\frac{1}{8}$th to 1,000 HP. Nor is this the limit—in fact, there is no work too heavy for a motor; the limit of its size is decided by the comparative economies of transmission or generation on the spot, of the powers required.

Tests of power lost in running a number of machines from one long shaft driven by a motor have shown that often 60 to 75 per cent. of the B.H.P. is absorbed in turning the shaft and pulleys, and bending the numerous belts. This loss is going on all the time the shaft is running, although the machines driven be only intermittently in use.

A useful basis for electric driving arrangements is, that groups of small machines taking together under 6 HP. may be driven from line shaft, if the shafting need not be more than about 30 ft. long for $1\frac{1}{2}$-in. to 3-in. shafts. For heavier machines the line shaft should be cut up into 10 HP. sections. But the engineer should consider each machine separately, with a view to driving by individual motors wherever it is at all practicable. It is not only a question of power losses, but of the advantage offered for convenient placing of the machines, and the increased efficiency obtainable by direct control of speed regulation. Lathes, drilling machines, planing, slotting, boring and milling machines, take individually small powers, but can often be arranged more conveniently for their work if driven directly by small motors.

Modern high-speed machine tools, using high-speed steel cutters, drills, &c., can be made to take much more power and consequently turn

out more work than was formerly usual. Most of the English-built lathes of the last ten or fifteen years' make could be adapted for the use of high-speed tool steel, and their former speed and output trebled. They can then be driven direct by variable-speed motors, and in this way some good results have been obtained. Careful experiments have shown that in a lathe, for example, most of the power is taken by the running of the machine and its work at the speed required, and that for medium feeds, the actual cutting takes only a small proportion of the total power used. This is shown in Table 1. The lathe in this test was run at varying speeds by a belt from a motor. The work to be operated upon was fixed in the lathe, but no cut was made. The cutting effort at a fixed feed was practically the same (about ·5 HP. in this case), but, of course, at the higher speeds much more metal was removed in a given time. The cost of the extra power for high speeds, compared with the value of work done, showed that the high speed more than doubled the overall efficiency, and to this must also be added the saving of power transmission losses when the machine was direct driven by a motor. The Tables 2, 3, and 4 are examples of group driving. The inefficiency losses of the shafting and belt driving are seen to be very high. In Table 3 it is shown that to drive the shafting, belts, and the work in four 8-in. centre lathes required 7·4 HP., whilst when all four lathes were taking their maximum cut, only 1·2 HP. was added to the load. Table 5 gives the power required for the driving of various machines, pumps, &c. All these results are from tests taken by the writer under working conditions of modern machines.

TABLE 1.—RELATION OF SPEED TO POWER.

6 *HP. Motor driving Lathe, Work fixed, but no Cut on.*

Speed of Motor, Revs. per Min.	E.H.P. to Drive Machine.
768	6·4
748	5·8
605	4·2
430	2·75
188	1·4
110	0·85

TABLE 2.—10 *B.H.P. Motor, running* 70 *ft.* × 3 *in. Shaft at* 205 *Revs. per Minute.*

Work done by Motor.	Total E.H.P. taken from Electric Mains.	Useful Horse Power applied to Work.
Running motor alone	1·07	...
Running shaft, belts, and countershaft gear	4·28	...
Running 5 small lathes, 1 radial drill, 1 shaper	8·56	4·28
Maximum load observed under work conditions	10·7	6·42

TABLE 3.—GROUP DRIVING.

10 *B.H.P. Motor, driving* 60 *ft.* × 3 *in. Shaft at* 205 *Revs. per Minute.*

Work done by Motor.	Total E.H.P. supplied by Electric Mains.	Useful Horse Power applied to Work.
Running motor light	1·07	...
Running shafting, belts, and countershaft gear	4·02	...
Running 4 lathes, with work fixed but no cut on	7·4	...
Average working load, using cast steel tools	8·6	4·58
Running 1 lathe with high-speed tool steel, heavy feed, cutting speed = 75 ft. per min.	9·3	5·28

TABLE 4.—GROUP DRIVING WOOD-WORKING MACHINERY.

Belt Drive from Shaft and Countershafting by 10 *B.H.P. Motor.*

Work done by Motor.	Total E.H.P. supplied by Electric Mains.	Useful Horse Power applied to Work.
Running motor light	1·09	...
Running shafting and belts light	2·68	...
Running wood-turning lathe light	3·05	...
Wood-turning lathe, heavy cutting	4·4	1·72
Band saw, 37 in. diameter pulley, speed of saw teeth = 3,500 ft. per min., light	3·65	...
Band saw, cutting 3-in. spruce	3·83	1·15
Circular saw, 26½ in. diameter, speed of saw teeth = 8,300 ft. per min., light	4·63	...
Circular saw—		
Cutting 7-in. dry beech	8·8	4·17
Ripping 3-in. dry spruce	5·2	0·57
Cutting 2-in. teak	4·7	0·07
Cutting 11½-in. teak	6·55	1·92
Cutting 9-in. spruce	12·6	7·97

TABLE 5.—POWER TAKEN BY ENGINEERS' TOOLS.

Direct driven by Individual Motors.

Type of Machine and work done.	E.H.P. taken by Motor.
Circular cold iron saw, cutting 14 in. × 6 in. R.S. joist	3·68
Circular cold iron saw, cutting mild steel billets, speed of saw teeth = 500 ft. per min.	4·2
Circular cold iron saw, cutting mild steel billet, saw teeth at 1,500 ft. per min.	10·5
Circular hot saw, cutting 6 in. × 6 in. steel billets, speed of saw teeth = 8,760 ft. per min.	46·5
Punching machine, punch 1-in. holes in $\frac{3}{4}$-in. boiler plate	5·4
Shears, cropping 6 in. × 4 in. × $\frac{5}{8}$ in. angle steel	13·3
Gate-shearing machine, cutting $\frac{1}{4}$-in. plate 6 ft. length of cut	6·0
Planer, planing mild steel—cutting stroke	3·05
,, ,, quick return of table	3·85
Planer, planing heavy cut on very hard steel—cutting stroke	7·0
Planer, planing heavy cut on very hard steel—quick return of table	5·3
Plate straightening rolls "mangling" $\frac{5}{16}$-in. plates 2 ft. wide	13·3
Pneumatic hammer, 7 cwt. size—striking	7·0
,, ,, ,, cushioning	13·4
Pneumatic hammer, 5 cwt. size—striking	7·0
,, ,, ,, cushioning	10·0
Milling machine, peripheral speed of cutter 7 ft. per min., feed of cut $\frac{1}{2}$-in. per min., width of cutter 130 mm.	6·5
Automatic lathe, making 1-in. screwed studs from bar	4·2
Steel foundry mill, grinding bricks, sand, &c.; revolving rollers, fixed pan; load varies according to the quantity and kind of material in pan	8-15
Foundry "rattler" revolving cylinder for cleaning castings	5·0
Vertical shaft turbine pump, direct coupled to vertical motor, 600 rev. per min., 6-in. pump discharge pipe, head 15 ft., pump under water when working	5·3
18-in. cupola fan, 4-in. discharge, 1,200 rev. per min.	4·8
14-in. fan, 6-in. discharge, 1,600 rev. per min., blowing 6 smiths' fires	6·0
Three-throw pump, raising 200 gall. per min., head 30 ft.	3·5
Three-throw vertical pump, raising 800 gall. per min. against a head of 91 ft.	23

Driving Arrangements.—The driving of line shafts by motors where a number of small machines are grouped may be either by belt from the motor fixed on the floor or wall, or by a chain drive from the motor fixed on a column, girder, or wall bracket. If a belt is used it should be thin and pliable, not too tight, and preferably endless. Where a good angle of drive cannot be obtained—for instance, where the motor must be fixed on the floor or wall directly underneath the shafting—a compound belt will give much better and steadier drive than a single one. *See* **Belting.**

Chain driving by a pitch chain gives a silent, positive drive, and the motor can be fixed quite close to the shaft. The chain pinion may be much smaller than a belt pulley, so that a speed reduction of 6 to 1 from motor to driven shaft may easily be obtained, which with a shafting speed of 200 revs. per minute allows of the use of a high-speed motor. Chain driving, however, is only successful in shops quite free from dust and grit. The chain should not be run too slack, or it wears rapidly, it must be carefully lined up, and should be lubricated with graphite. Means for tightening the chain should be provided.

Cut spur-gearing may in some cases be adopted for line shafts, where the motor can be fixed to the wall or a good foundation. For direct coupling of the motor to a machine, cut metal gearing can be run up to 1,000 ft. per minute, but usually, on account of the noise and the rapid wear of metal teeth at high speeds, raw-hide pinions are used on the motor. A raw-hide pinion driving a cut gear can easily be run up to 2,000 ft. per minute.

There is no economy, however, in using high-speed motors and multiplying the reduction gear; on the contrary it is better to put in slow-speed motors, because their efficiency is greater. Thus, a high-speed motor and a train of reducing gear may cost slightly less than a motor running at half the speed, the latter being about 10 per cent. more expensive. But its efficiency will be 6 per cent. higher than the high-speed motor, and as it can utilise electrical energy at a rate equal in a year to twice its capital cost, the difference of cost of installation may be saved many times over in a single year.

Selection of Motors.—One of the strong points of the electric motor is its capacity for carrying overloads. Makers will guarantee an overload capacity of 25 per cent. for short

periods, 10 per cent. continuously, or 40 per cent. intermittently, but at any rate, with good makes of British motors, more than this can be carried on emergency. The rating of motors is an important matter, and full particulars of the working conditions should always be given to the makers when the motors are ordered. Motors for continuous running at steady full load must be designed with that capacity, whilst those on which the load is likely to be variable, even although they may sometimes be overloaded for short periods, may be rated higher. For intermittent work having periods of rest, such as crane and hoist work, capstans, &c., they may be rated higher still. As the rating has a considerable influence on the price, it should be carefully considered, but at the same time a good margin of power on the probable requirements should always be allowed.

When laying down an electric power plant, the choice between alternating or continuous current depends entirely upon circumstances. Where the load is steady and the speed constant, induction motors may be used. But one of the chief advantages of electric driving for engineering works is the facility for direct speed regulation.

Direct current shunt-wound motors, if their fields are kept fully excited by separately connecting them across the mains, may, either by applying different voltages to, or using rheostatic control of their armature circuit, be run at speeds varying, say, from 800 to 180 revs. per minute in a 10 HP. motor. Then by adding shunt regulation a variation of speed in a motor designed, say, for 800 revs. per minute may be ranged from 1,500 to 180 revs. per minute.

In engineering works the cost of power is usually about 5 per cent. of the cost of output. Electric driving may save 50 per cent. of this, representing 2½ per cent. of the total. But time and labour are 50 per cent. of the total, and direct electric driving with speed regulation may in many cases save 60 per cent. of the time, representing 30 per cent. of the total cost of output. Motors are cheap, simple, and reliable. Their costs for repairs and maintenance are less than for any other class of machine for their purpose. They can be adapted to any class of work, will run at widely varying speeds or loads with good efficiencies, and if properly selected and installed have a long life without depreciation. The characteristics of series, shunt, and compound motors are described under **Electric Motor,** and for alternating current, under **Induction Motor.**

Electric Furnace.—Electricity is used for the smelting of metals, the production of calcium carbide, carborundum, graphite, and in other manufactures where the production of extremely high furnace temperatures is necessary.

An electric furnace usually works on the principle of the formation of an arc between carbon electrodes, one of which is in the form of a chamber, containing the material to be smelted, and connected to the +. The arc formed between it and the – carbon rod playing upon the face of the material, quickly produces temperatures unattainable by any other means.

Electric heating furnaces are also used, and consist of tubes or chambers of refractory material having wires or strips of platinum foil wound upon them. The material is placed within the chamber, and the windings are made incandescent by the passing of heavy currents, and great heat is thus produced in the furnace.

Electric melting furnaces are now constructed for steel production, whereby steel is produced direct from the ore. It is probable that the electric furnace will be very much developed in the production of steel and other metals and alloys as it becomes possible to reduce the cost of the generation of electric power by the improvements in machinery. The utilisation of blast furnace and coke-oven gas, the economies effected by the centralisation of generating plant, and the cheap supply from the stations of the large power companies will all help to extend the use of the electric furnace.

Electric Heater.—The superior efficiency of heating by radiant heat over the usual method of convection, has brought the electric heater into use. For the warming of rooms, halls, &c., the electric heater takes the form of large incandescent electric lamps specially constructed to convert electricity into radiant heat rather than light. The many advantages of cleanliness, convenience, and efficiency of heating by electricity, and the absence of fumes and

smoke, are rapidly bringing the electric heater into extensive use, and, as the supply of current becomes more general, this method of heating will be more largely adopted, being in every way superior to the present methods of coal and gas fires.

Electric Hoist.—The term hoist is very loosely applied in practice, and in effect covers a wide range of lifting appliances. *See* **Hoists.**

Electricity.—It is not possible to define electricity any more than we can define other elements and forces of Nature. But we know that it exists as a natural force which produces certain phenomena, and by the study of these effects we may trace its laws, study its properties, and utilise its powers for practical purposes. From these studies we find that it may be regarded as a fluid, very similar to water in its behaviour. Although electricity itself cannot be felt, seen, or weighed, means can be devised for indicating its presence, and measuring its strength and quantity. We can produce electrical activity and cause it to *flow*, and to exert its force in certain ways, confining its passage to prescribed paths, and using it for any one of the numerous purposes to which we have learned to adapt its powers.

Whilst a knowledge of the existence of electricity is very ancient, it is only within recent times that it has been applied to engineering purposes, but in that direction it has made such progress that the practical engineer must include electricity as one of the most important branches of his study.

The subject is dealt with under numerous headings in this work, and reference may be made directly to any special point of electrical practice upon which information is desired.

Electric Lamp.—A lamp for producing illumination by using electricity to heat to incandescence a carbonised filament, to produce and maintain an electric arc, or a body of luminous gas, mercury, vapour, &c. *See* **Arc Lamps, Incandescent Lamp, Nernst Lamp, Mercury Vapour Lamp,** &c.

Electric Lift.—Electricity has, to a very great extent, revolutionised lifting machinery, and when applied to passenger and goods elevators, is, if properly carried out, safe, expeditious, and economical. The largest field for the use of passenger and goods lifts is in connection with hotels, office buildings, warehouses, &c., where the supply of power for the elevators is in many cases taken from public supply mains, and as the public supply of electricity is now much more common and cheaper than that of hydraulic power—its only competitor under these circumstances—the electric lift has been extensively adopted in such buildings. It possesses many advantages of convenience and adaptability in working, and the cost of installation is not more than that of the hydraulic lift. With power-water at 6d. per 1,000 gallons, and electricity at 2½d. per B. T. unit, the working costs of an electrically driven lift will be 50 per cent. less than the hydraulic system; so that wherever electricity is available, its adoption for new installations, or for the conversion of existing hydraulic lifts, is justifiable on the consideration of working costs alone. The motor, switchgear, &c., for the operation of an electric lift, may be placed on the top or any intermediate floor, but if space is available, is preferably fixed on a good foundation at the bottom.

The motor is usually compound-wound, with a strong series winding to give a high starting torque, which winding is cut out as the motor is run up to full speed.

Three methods of control are used, the choice depending upon the speed and length of travel, and whether an attendant is required to travel with the cage, or not. Thus the working of the lift may be controlled by outside ropes, operated from the room on any floor, which system is often convenient for goods lifts; or by a switch lever in the car, worked by an attendant, as is usual in passenger and luggage elevators in hotels, &c. A third method now much used for express elevators, is by *push button control*, when no attendant is required. In either system the gear is automatic; that is to say, the operator simply switches the current on and off, and the motor is automatically started and accelerated. The motor is connected through suitable reduction gearing to a winding drum, from which the car is suspended, that runs between guide posts fixed up the corners of the well or shaft in which it travels. Limit switches are provided so that the car cannot be overwound, and safety catches are also so arranged

on the car itself that in the event of the rope breaking it cannot drop, but is suspended in the shaft. Thus, if the rope were to break, the passengers would be hung up in the shaft until the spare rope was fitted, which could be done in a very short time. With the high factor of safety allowed in the steel wire suspension ropes now used, however, such accidents are almost unknown.

The *press button* system of control is very complete and has one great advantage, namely, that having once been put in motion the lift cannot be interfered with, except by the passenger inside, who can stop it anywhere in emergency, until it has completed the journey for which he started it.

Thus, suppose a passenger on the ground floor wishes to ascend to the fifth floor; on entering the car he presses No. 5 button in the car. This starts the lift, and also sets the controller, so that upon arriving within a yard or two of the fifth floor the speed is reduced and the lift is brought gradually to rest at the door of that floor without any interference from the passenger. During this journey, and until the passenger has safely alighted, all the other press buttons are inoperative, for the shaft doors at the different floors on being opened break the main circuit; so that until the cage is empty and the shaft door has closed, no other person can start the lift; whilst these doors themselves can only be opened by a passenger arriving in the car.

The press buttons set the controller by means of relays. Buttons are fixed both inside the cage and in the rooms.

When a passenger steps into the car, say at No. 3 floor, he presses the button corresponding to the floor he wishes to stop at, say No. 4; completes his journey and leaves the cage.

Another passenger then presses the button marked No. 5 fixed in the room on the fifth floor, when the lift will ascend to him. He may then enter the cage, press No. 2, and emerge on the second floor. A third person on the ground floor can then press No. 1 button there, when the cage will descend, and he in turn may journey to any floor he wishes.

The system of button control is thus very complete; every possibility of accident or misuse is provided against, and gradual starting and stopping, enabling express travelling speeds to be safely used, is automatically effected without dependence upon the skill or attendance of the passenger or an operator.

The up-to-date express electric lift is in fact a literal example of the "You press the button —we do the rest" saying of the electrical engineers.

Electric Lighting.—Illumination by the use of electric lamps supplied with current from a central generating plant of dynamos or batteries.

Electric Lighting of Workshops.—This is carried out either by arc or incandescent lamps, the choice depending entirely upon the class of work being done in the shops. Thus whilst boiler shops, erecting shops, forges, steel works, &c., can be efficiently lighted by arc lamps; other departments, machine rooms, moulding, core making, and pattern shops, where direct lighting without shadows is required, require incandescent lamps fixed to each of the machines or benches, or the use of portable lights, with arc lamps fixed on the walls or ceilings for general illumination.

For outside lighting of yards, wharves, or railway sidings, open-type 10 ampère arc lamps fixed on latticed steel or wooden posts 25 to 30 ft. high, and 60 to 70 yds. apart give sufficient illumination. For shipyards or outside work where a working light is required, or for warehouses, sheds, &c., "flame" arc lamps 18 to 20 ft. high and 25 to 35 yds. apart will be found to give a brilliant effect. For heavy machine and erecting shops either flame or enclosed arc lamps of smaller powers should be adopted, because they have usually to be fixed on the walls or columns below the travelling cranes, and having more local diffusion of the light, smaller units of 5 to 7½ ampères, closer together give the best results. In shops where there are no travelling cranes, and even where there are, if these are not more than 20 ft. high, it is better for general illumination to suspend the arc lamps from the centre of the roof. For erecting shops a good working light will be given by one 10 ampère open arc lamp for 1,500 sq. ft. of shop area. For foundries

and moulding shops (where local lights are also required) one 5 to 7½ ampère lamp for 3,000 sq. ft.; for steel furnaces, bridgeyards, &c., one 10 ampère lamp for 6,000 sq. ft.; for the general lighting of machine shops, 7½ ampère lamps, 20 ft. high, at the rate of one for 2,500 sq. ft. of area, will be sufficient.

Incandescent lamps of 16 candle-power are commonly used, but it will be found that an 8 candle-power lamp is quite sufficient for fixing to such tools as drilling, planing, and shaping machines, boring mills, saws, and the heavier lathes. Smaller machines, such as lathes, grinding machines, woodworking, or other high-speed or accurate work may require 16 candle-power lamps. Wherever possible, the lamp fitting should be fixed to the machine and be so arranged that the operator can place it in the best position for his work. On large lathes, with long beds, a lamp fitted to the tool rest with a sliding contact running on bare (but protected) wires fixed on the back of the machine, is a most useful arrangement.

Arc lamps, in the case of foundries, where dust and dirt prevail, and there are not great fire risks from falling carbon sparks, are often used without globes. Where the lamps are fixed above 15 ft. high, the function of the globe should be to prevent falling sparks of carbon, not to cover up the arc. The heavily obscured globes often found on arc lamps in workshops, are not required, and often absorb 50 per cent. of the light; even a light ground glass globe will absorb 30 per cent.

With enclosed arc lamps a clear glass outer globe should be used; the inner globe gets quite sufficiently obscured by the gases enclosed.

Where many arc lamps are installed, and wherever they cannot be reached from the travelling cranes in the shops, or without the use of long ladders outside, some one of the numerous patterns of self-sustaining contact gear should be fitted. Where long ladders, requiring two men to carry them, and the help of a third to rear them, have to be used, the cleaning and trimming of lamps is an expensive business.

Two men can be kept quite busy looking after thirty open-type arc lamps with ladders; but with lowering gear fitted, one man can keep in order 100 open-type, or 250 enclosed lamps scattered over a works. This, of course, is apart from repairs, and the thorough cleaning and overhauling which every lamp should receive say every three or four months.

The lighting of offices, stores, &c., may be by 8, 16, or 25 candle-power lamps as required. Whilst Nernst lamps may be used for large open rooms, halls, staircases, &c., and give a good and economical lighting effect, the incandescent glow lamp is the best for small offices, desks, or wherever the light has to be close to the eyes. For a portable desk lamp, a green-cased shade, and a 16 candle-power frosted glow lamp, is a very nice arrangement, and not tiring to the eyes. For the general lighting of rooms and offices about 1 watt per sq. ft. of area, that is, one 16 candle-power lamp for 60 sq. ft. gives a brilliant effect.

A much better diffusion of light is obtained by scattering a number of small lamps than by grouping, and 3 and 5 light fittings should be avoided in office lighting.

For the drawing office; the best, most evenly distributed and shadowless lighting is by inverted arc lamps. These throw the light up to the ceiling, or to a white screen which reflects it downward and gives an illumination more satisfactory than any arrangement of lamps on the drawing boards or desks. The inverted arc lamps should be spaced so that the circles of light on the ceiling touch and overlap a little. One 10 ampère lamp for 900 ft. of floor area will give a perfect light for drawing office work.

For photo printing of drawings by electric light, with an open flat frame, two 15 ampère open arc lamps are required, and should be used in a dark room. Special machines are made for this purpose, however, and by their use copies of engineers' drawings can be printed from tracings in a time regulated to give the best results according to the paper in use. Ordinary blue prints can be printed in one and a half to two minutes, white prints taking about four minutes.

Electric Motor.—If a continuous current dynamo, instead of having mechanical energy applied to its shaft for the turning of its armature, has electricity from another source brought to excite its field magnet system, and also to

the brushes of its armature, the armature will revolve. The machine then becomes an electric motor, and will deliver at its pulley as mechanical energy, the electrical power supplied to its windings.

To explain this action; say in a shunt-wound motor designed to give 10 HP. on a 100 volt circuit; we may consider first the magnet windings of fine wire having a resistance of 8·3 ohms. This will allow a current of 1·2 ampère to flow in the field coils when they are connected across the mains, so producing a strong magnetic field in the air gap. If now, we send a current through the armature we produce another magnetic field, and the reaction between the two will cause the armature to revolve. The armature then becomes a conductor moving in a magnetic field, and therefore produces currents, but in direction opposing the current supplied from the main. If the motor be running with no load on its pulley, the E.M.F. produced by its armature (or "counter-electro-motive force") will be almost equal to that of the mains, and as the mains have to force current against an almost equal back pressure, very little will flow.

When the braking effect of a load on the motor pulley is felt, however, this tends to reduce its speed, the back E.M.F. falls, and more current flows from the mains. Thus the E.H.P. taken from the mains is regulated by the brake load on the pulley. The E.H.P. or "Electrical Horse Power" supplied to the motor is found by measuring the ampères taken from, and volts pressure in, the mains, when:—

$$\frac{\text{ampères} \times \text{volts}}{746} = \text{E.H.P.}$$

The inefficiency losses due to the current taken in exciting the field and overcoming the friction of the bearings will not in a well-designed motor be more than 14 per cent., that is a "Commercial Efficiency" in conversion of electrical power input to mechanical power output = 86 per cent. Therefore:—

$$\frac{\text{E.H.P.} \times 86}{100} = \text{B.H.P.},$$

so that the actual work being done at any moment by the motor may be readily measured in "Brake Horse Power."

As with dynamos, three different ways of exciting the fields of motors are adopted, shunt, series, and compound, and in special cases differential windings are used.

Shunt-Wound Motors are used wherever a constant speed of working is required, as in the driving of machine tools, &c., and this type is only slightly affected in speed by variations in the loading. The variation, according to the type and size of motor, may be from $\frac{1}{10}$ to 4 per cent. from no load to full load. The shunt motor depends for its speed upon the strength of its field and the voltage applied to its armature. If resistance be inserted in its armature circuit so as to cause a fall of pressure the speed will be reduced. If resistance be inserted in the field circuit, the field is weakened and the speed increased. By either, or a combination of these methods, considerable ranges of speed may be effected.

If a motor is specially designed to run at variable speeds, however, it is arranged that for slow speeds its field coils shall be connected in parallel, thus strengthening the field and reducing the speed, in series for the normal speed, and with resistance in circuit to weaken the field to increase the speed. In this manner speed ranges of 6, or even 8 to 1 can be obtained by shunt control alone, with full power at all speeds.

Variable speed motors are used for direct coupling to lathes, drills, planers, and other machines where different working speeds are useful.

Series-Wound Motors.—In a series-wound motor the field is excited by sending the whole of the current taken from the mains and passing through the armature through a few turns of thick wire on the magnets. Thus the strength of the field depends upon the current passing in the armature. At no load this current is small, the speed is therefore high, but as the armature is loaded, the field is strengthened and the speed reduced.

Series motors are used for work where this characteristic is either useful or immaterial. Thus in machines such as shears punches, &c., where heavy flywheels are used to do the work and a constant speed is not so important, or in fans where the load is always the same, and speed is kept constant to the voltage of the

mains, series motors may be used. They are also employed for cranes and lifting machinery where their self regulation of speed enabling light loads to be handled at high speeds, and heavier loads at lower rates, exactly suits the conditions of working. Series motors are also used for electric tramway and railway work.

Compound-Wound Motors have both series and shunt windings on their field coils. They are used for special requirements, such as electric capstans, electric lifts, &c., where the inertia of the load is great and the starting torque must be greater than the running torque. With these motors a strong, steady starting effort is obtained, and with suitable controllers the series winding may be short circuited after the starting resistance is cut out and rapid acceleration effected; this winding coming in again before stopping, and giving a steady pull up very suitable for the working of passenger lifts. Usually, the series coils are wound in the same direction as the shunt coils, so that the motor speed is less when the load is heavy, the series windings helping the shunt winding to produce this effect. But in special cases, such as cotton-spinning machinery, where absolutely constant speed is required, the series is wound to oppose the shunt winding. Then when the load becomes heavier more current flows in the series coil, neutralising the shunt and so weakening the field, thereby increasing the speed.

Whilst the motor, if only shunt-wound would run slower with increasing load, this fall of speed is exactly compensated by the action of the series winding in proportion to the load.

Before selecting a motor the special work it is required to do should be carefully considered, in order that shunt, series, compound, or differential windings may be adopted to suit the conditions. Motors for outside or damp situations, or for use in dusty places such as foundries, grinding mills, &c., or in mines and places where explosive gases may be present, can be built so as to be air-tight, or even to run under water. But as totally enclosing a motor reduces its efficiency from 20 to 30 per cent., this should only be done where really necessary.

Under ordinary conditions the medium speed open type motor is the most suitable and efficient. Electric motors can also be run on alternating current circuits, so that wherever electricity, either as direct, or single, or polyphase current is available, the advantages of electric power may be obtained. Alternating current motors are described, and their theory explained under **Single-Phase Motor, Induction Motor.**

Electric Switch.—Apparatus for completing and breaking an electric circuit. *See* **Switch.**

Electric Traction.—Hauling by means of electric power, either by locomotives or by the fitting of motors to the coaches. Several different systems are used. In this country the *third rail* system has so far been adopted. In this the + current is carried by a third rail, the train motors collecting by a plough, and the two running rails forming the return – path. On the Continent however, overhead conductors are in some instances used. For short distance suburban lines, having frequent stopping places, electric traction has been very successfully used, one of its advantages being that rapid acceleration enables high speed to be attained on short runs, thus allowing quick and frequent services of trains to be given.

At present the indications point to the increased use of electricity for traction work, and it is probable that the use of high-pressure alternating current, carried by overhead conductors, and transformed down on the train for use in low tension, single-phase motors, will be the system of working high-speed, long distance traffic on railways to be constructed in the future.

Electric Tramways.—In electric tramway power stations (except in very large systems serving an extensive area) the electricity is generated at a pressure of 550 to 600 volts continuous current. *Boilers* of the Lancashire, or water-tube type, or in many instances both types, are installed. The demand for power on a tramway station varies at different parts of the day, and the quick-steaming qualities of the water-tube boiler render it very useful for dealing with emergency loads, such as busy hours of the day, or bad weather produce. Mechanical stoking, and forced draught furnaces are usually installed,

and steam raising economies are effected by the use of economisers, or feed-water heaters of some other type.

The Engines may, according to circumstances, be either of the slow-speed horizontal, or high-speed vertical type, but in all cases are connected direct to the dynamos. They are usually triple or quadruple expansion condensing, and in some cases superheated steam is used. Steam turbines are in some cases installed in electric power stations.

The Dynamos are multipolar compound-wound machines. *See* **Dynamo.**

A storage battery is very often included in the power station plant, and when worked in conjunction with an automatic reversible booster plays an important part in the economical working of the station. *See* **Storage Batteries.**

The Switchboard receives the electricity from the generators and distributes it by the feeder cables to the various parts of the system. The overhead lines, or underground conductors as the case may be, are divided into sections, each section being fed by a feeder at full pressure from the station. By this arrangement all parts are kept at equal pressure, and heavy lines or conductors are not required (as would be the case if the line were continuous and fed only at one end), each section supplying current at full pressure to a small number of cars which pass from section to section and can thus run at full speed on the most remote as well as the nearer portions of the system.

The Permanent Way is very solidly constructed with a view to making it really permanent, as, the tramways being in public thoroughfares, repairs or renewals are both expensive and obstructive. Solidity of construction also has a most important influence upon the wear and tear of the rolling stock. The roadway is prepared by excavating to the depth necessary, and a solid bottom is formed. The rails are then laid in the trench, supported at intervals, and kept to the paving level. The trench is then filled with concrete, well rammed under and around the rails, up to a height to allow for the paving setts. The setts are laid on the concrete, rammed to the contour of the street, and the joints filled in with boiling pitch. The rails are of girder section, having a base of about 7 in., standing 7 in. deep and the top edge grooved to receive the wheel flange. They weigh from 105 to 110 lb. per yard. Their ends are butted together and the joint connected by fish-plates. At each joint a short girder about 2 ft. long is placed under the rail, and its top flange is riveted to the base flange of the rail. This makes a very secure anchor plate and prevents any lateral movements of the rails at the joint. As the rails have to form the return path for the current it is important that their contact at the numerous joints should be electrically perfect as well as mechanically rigid. The rusting of two iron surfaces would spoil their electrical contact and mean loss of power in forcing the current through, or, when the contact became bad, the current might be diverted to gas or other pipes in the vicinity and cause corrosion of their surfaces by electrolysis. The joint is therefore bridged by a copper bond making good contact with the rail on either side, and the two lines of rail are also copper-bonded together at intervals. Being thus connected in parallel, each line carries half the return current which is transmitted through the wheels of the running cars. The best method of bonding, however, is to make the rail continuous by welding it at every joint, and this method is now coming into general use. The welding is carried out by cast welding metal on the joint of the rail either by the "Falk" process, or by the "Thermit Welding" system. *See* **Thermit.** Electrical welding has also been used for this purpose. Several large systems of tramways have used one or the other process, and the advantages of a welded rail are now generally recognised both for mechanical and electrical efficiency, and the saving of repairs to plant and track effected.

The Overhead Lines are of hard-drawn copper wire. They are supported by insulated hangers from cross wires, these latter being carried from standards fixed on the sides or in the centre of the roadway. In narrow streets the cross wires are often carried by the buildings.

In Conduit or Surface Contact Systems, the conductors are laid in the ground between the rails, the current being collected by a plough or skate fitted underneath the car.

The Motors.—The cars, having accommodation for sixty to eighty passengers, carry two electric

motors, each of 25 to 30 B.H.P., according to the power required to negotiate the gradients of the line, and also the necessary switch gear and controllers. The motors are, where the "Series Parallel" control is used, of the series-wound type, but on lines where the system of "Regenerative control"—now coming into use on account of its superior efficiency and economy in wear and tear of plant where heavy gradients are met with—is adopted, shunt, or compound wound motors are employed. *See* **Electric Brakes.**

The motors are carried under the body of the car on the framework of the wheel truck. They are connected by suitable reduction gear to the wheel axles. Tramway motors have to work under very adverse conditions of exposure to damp and mud and rough usage, so that a special type of totally enclosed, substantially designed machine has been evolved for this class of service.

The Controller, forming the switch gear and rheostats for starting, stopping, reversing, and regulating the speed of the motors, is also of special design. Where series motors are used, the controller is so arranged that in starting the two motors are placed in series across the mains (represented by the trolley wire and the rails), the voltage is then divided equally between them, and half speed is attained. The controller then passing on, places each motor in parallel on the mains, when it receives the full pressure and runs up to full speed. Intermediate speeds are obtained by inserting resistance in the circuit.

Brakes.—On account of the great weight and the speed of travelling, and for safe running on the heavy gradients met with, powerful brakes are required. Several kinds of brake are used, hand, mechanical, pneumatic, or electrical. To provide against emergency or failure, at least two, and often three types are fitted, as well as the brake power which can be obtained by reversing the current in the motors.

Accidents never happen through absolute failure of all the brakes, but are usually caused by want of skill or presence of mind in their application. If the brake be too suddenly or powerfully applied to the wheels they will skid; brake friction can only be obtained whilst the wheels are in motion. For this reason an electro-magnetic brake acting directly on the rail is now much used. *See* **Electric Brakes.**

The Electrical Power Circuit.—The current, starting from the + terminal of the dynamo, goes to the switchboard, and thence by one of the feeder-cables to a section of the overhead wire, or the conduit conductor. It then passes by the contact of the trolley wheel fixed on the top of the car, or by the plough or skate fitted underneath it, to the controller, and so to the series windings of the motor field; thence through the armature—causing it to revolve and so doing the work of turning the car axle—it returns through the wheels, and by way of the continuous length of rails which at the station end are connected to the – terminal of the dynamo.

In tramway systems covering large areas, as in London, Manchester, and other large cities, the power is generated at the central station as alternating current. High-pressure cables transmit the current at 3,000 to 6,000 volts to sub-stations placed in convenient centres. Rotary converters, consisting of 2 or 3-phase induction motors coupled to continuous current generators, are there installed. The generators produce continuous current at the pressure required, and from the switchboards at these sub-stations the power is distributed locally by feeders as already described.

Electric Traveller.—These travellers are constructed in a wide range of loads, spans, and speeds, and are made as both single and multi-motor cranes.

Single motor travellers may have the motor and the bulk of the gearing arranged at one end of the main girders. The motor drives a shaft from which the various motions are taken by means of friction clutches, the crab being driven by cross shafts. Other single motor travellers have the motor on the crab itself, and the main travelling gear is driven by a cross shaft. The favourite traveller is, however, of the multi-motor type, where a separate motor is applied to each motion. The usual arrangement of girders and end carriages is not materially different from that adopted for steam and hand travellers; but increased speeds have involved

stronger construction, especially in the side stiffening of the girders and in their attachments to the end carriages. Electro-magnetic brakes are fitted to the hoisting gears, foot brakes are sometimes provided for the longitudinal travelling motion, limit switches and mechanical brakes are also frequently arranged for.

The electric crab is variously built. The cheeks are of cast iron, or steel plated. The drum or drums are spirally grooved to carry the wire rope now generally used instead of chain. The adoption of the motor drive has had the result of bringing the worm reduction gear into general use, the worms being multiple threaded. Spur gears have generally displaced the bevel gears used on the older travellers, and these are machine cut.

Travellers of above 15 or 20 tons power usually have a second hoisting barrel for light loads, either operated by clutches or else by a separate motor. This is termed the *auxiliary hoist.*

Current is supplied by bare copper wires strained the length of the traveller track, running either in the hollow of the runway girder, or else along the roof principals. Gun-metal shoes or trolley poles collect the current, which is led to the switchboard by suitable cables. A separate controller for each motor is located in the driver's cage, and is connected up by cables to the switchboard and to its motor. The controllers are usually of the tramway type, but many are fitted with liquid resistance. The connection between the moving crab and the cage on the main girders is maintained by bare copper wires strained over the length of the span, engaging with collectors fixed on the crab. Electric travellers can be driven by all classes of current, continuous, single-phase, and polyphase. The usual voltage is 220 to 500. Examples of travellers are given in Figs. 189, 190, Plate XIII. The following are a few leading particulars of the cranes in Fig. 190 :—

70-ton Crane.

	Per Minute.	Motor.
		B.H.P.
Main Hoist -	70 tons at 5½ ft.	41
Auxiliary Hoist	15 tons at 30 ft.	47
Travelling - -	120 ft.	32
Cross traversing	60 ft.	16

100-ton Crane.

	Per Minute.	Motor
		B.H.P.
Main Hoist -	100 tons at 4½ ft.	47
Auxiliary Hoist	15 tons at 30 ft.	47
Travelling - -	90 ft.	32
Cross traversing	50 ft.	16

Electric Welding.—Electricity is largely used for the welding and brazing of metals. For welding pieces of large sectional area, heavy currents of low pressure are required. Iron or steel sections such as draw bars, &c., can be so efficiently welded, that the strength of the joint will be almost equal to that of any other part.

For work such as bars of 1 inch diameter section, alternating currents of about 20,000 ampères at one volt are used. The work is fixed in clamps carrying the current, and so arranged that when the metal reaches a proper heat, lateral pressure is applied, forcing the ends of the bars together, and so making the weld.

The following paragraphs have special reference to the Thomson patent process, the machines for which are supplied by the Electric Welding Co., Ltd., some of which are shown by Figs. 191-194, Plate XIII.

The essential feature of this process lies in the heating up which is first developed in the interior of the parts to be welded; that is within the metal at the joint (the ends being already in contact) and so diffuses over the areas in contact. As the heating takes place only after contact no oxidation can occur, and the welding heat does not extend beyond the metal that is actually between the clamps. As soon as this heat is reached, the current is cut off, and the pressure necessary to complete the weld is applied.

Around this elementary process a number of more or less specialised machines have been developed. The work of the engineering smithy absorbs only a very small amount of welding by comparison with some other industries. As the HP. absorbed in forcing the electricity through the metal is for a short time very great, the capacities of machines have to be graded by cross sectional areas to be welded, and the maximum HP. of the generator. So that a machine for tubes or wire would not be suitable, say, for the engine smith or angle-iron smith.

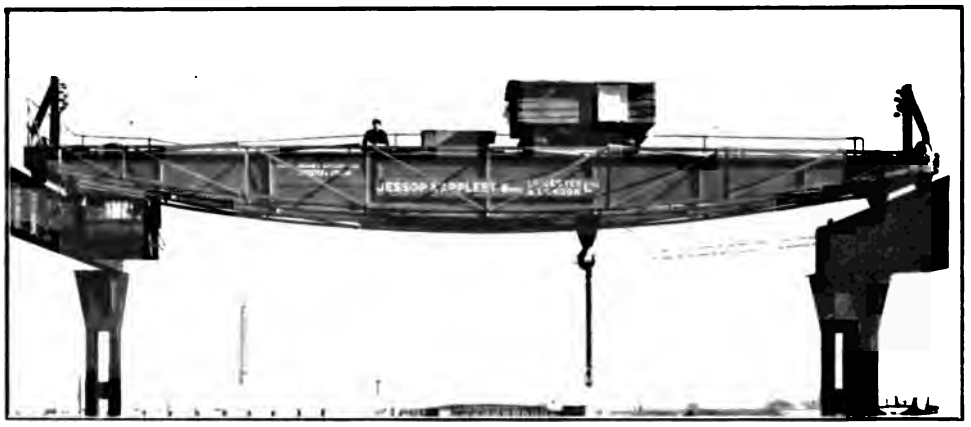


Fig. 189.—12-Ton 3-Motor Electric Traveller, 52 Ft. 6 In. Span. (Jessop & Appleby Bros., Ltd.)



Fig. 190.—Electric Travellers of 70 and 100 Tons Power. (Joseph Adamson & Co.)

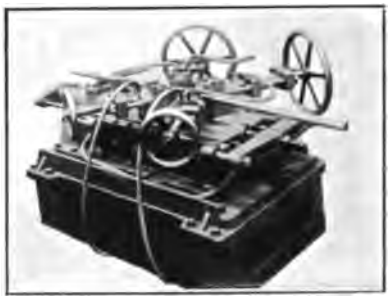


Fig. 191.—Electric Welder with Hydraulic Pressure Device. For Rods up to 2 Inches Diameter.



Fig. 192.—Electric Welder for Tubes up to 2 Inches.

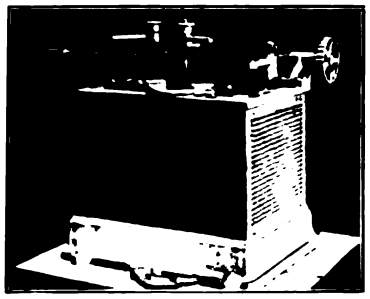


Fig. 193.—Large Electric Welder for Bars.

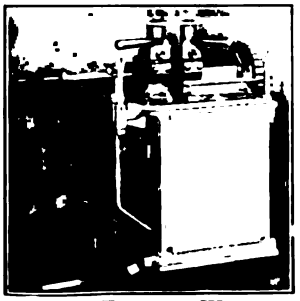


Fig. 194.—Small Electric Welder for Wires.

We cannot describe in detail these different machines, but they are made for cycle work, for wire, tubes, pipes, tyres, tools, small arms work, tram lines, electrical cables, and engineers' work. Some are hand operated, and others are automatic in action.

Alternating current generators are used, specially designed for the work. Current from alternating supply mains can be employed, or direct current, provided a motor alternator is employed to convert the direct to alternating.

The welding apparatus is mounted on a suitable stand at a convenient height, and comprises a transformer, provided with clamps suitable for holding the class of work to be united, together with mechanical means for pressing the ends together. This is either hydraulic, or hand operated. In the smaller sizes the pressure is applied, and the current shut off automatically. There is a reactive coil for controlling the current in the welder, to suit the different sections which have to be welded; a break switch by which the circuit is opened and closed in the primary circuit, and a water circulation in the secondary circuit.

The output of these machines can hardly be stated in general figures, since it depends on the machine, and mass of the work, and the hand operated, or fully automatic character of the machine. Between extremes it has ranged from 300 to 8,000 welds per day of ten hours. Mr Wallis-Jones states that the following table may be taken to show the approximate time and power required for welding various sections and metals.

GENERAL TABLE.

IRON AND STEEL.			COPPER.		
Area in sq. ins.	Time in secs.	HP. applied to Dynamos.	Area in sq. ins.	Time in secs.	HP. applied to Dynamos
0·5	33	14·4	·125	8	10·
1·	45	28·0	·25	11	23·4
1·5	55	39·4	·375	13	31·8
2·	65	48·6	·5	16	42·
2·5	70	57·0	·625	18	51·9
3·	78	65·4	·75	21	61·2
3·5	85	73·7	·875	22	72·9
4·	90	83·8	1·	23	82·1

A record of one week's welding done in an engineer's smithy, making cranes and winches, by a single welding machine, is:—180 winch stays, 80 winch connecting rods, 41 brake straps, 212 winch handles, 168 eccentric rods, 168 piston rods.

The value of such a system perhaps lies less in its application to the ordinary jobbing work of the smithy than in industries requiring a large amount of repetition welding, as in the manufacture of tyres, chains, cycle parts, coach hardware, railway carriage work, printers' chases, special tubes, tramway rails, &c., and in the union of alloys that have been hitherto joined by brazing. All the welds are butt welds, and no preparation of the ends is necessary. The method thus affords a most favourable contrast with the methods adopted at the forge, where ends have to be upset, and scarfed, or tongued, &c., and especially in angle sections, where portions have to be cut away and lapped, resulting in a very bunchy joint which must be afterwards finished and smoothed with considerable expenditure of time. Further, whereas in the forge method heating and distortion some distance away from the joint are unavoidable, in the electric process the heat is so sharply localised that finished work can be welded without damage.

Arc welding is much used for making good defects in steel castings, building up new teeth on gear wheels, &c. It is often done in such a way as to be worse than useless, holes are filled with metal made so hard that it cannot be machined, and is also not welded to the other parts. A little study of the process, and skill on the part of the welder enable him to produce such results that many defective castings might be saved. Continuous current at 100 to 120 volts is used. The + conductor is connected to the work, and the – cable is attached to a holder having a carbon rod fixed in its end. A steadying resistance—adjustable to give 100 to 600 ampères according to the size of the work—is placed in the circuit. The carbon rod is brought into contact with the work, and then withdrawn a short distance. An arc as much as 6 inches in length can be drawn out, and it is upon the regulation and working of this arc that the success of the operation depends. The

metal instantly fuses under the arc, and bits of steel are fed under it and melted until the crack or hole is filled, when the heat is gradually reduced until it falls to proper welding heat, when it is well hammered, and becomes firmly united to the surrounding parts.

In the "Voltex" system of electric welding a double-pole tool is used. The arc is formed between two carbon rods arranged at an angle of about 47 degrees in each other. A magnetic effect of the arc blows it out to one side, and a long flame like that of a blowpipe is produced. This is held closely to the work according to the heat required. The carbons used are specially made, and contain a percentage of iron oxide which combines with the carbon in the arc, and reduces it, so that it is all consumed instead of combining with and hardening the metal in the weld.

In this system the heating is perfectly under control; soft, homogeneous welds are produced, a large area can be heated, and work of all sizes and shapes can be operated upon either for welding or brazing. Iron, steel, copper, brass, and other metals can be electrically welded and brazed, lead burning and soldering, the hardening and tempering of machine tools, milling cutters, &c., can also be easily and quickly carried out with a cleanliness, quickness, and certainty of results which no other method of heating can effect.

Electrode.—The plates or rods acting as + and − terminals in an electrolytic cell. The + terminal is called the "Anode" and the − the "Cathode."

Electro-Dynamometer.—A Wattmeter for use on Alternating or Continuous Current circuits. A coil wound with heavy wire is pivoted, and fine wire coil fixed. A torsion spring keeps the coils at right angles to each other until a current passing in them causes an angular displacement of the moving coil in proportion to the pressure × current at any instant, giving a reading of the value of the momentary power in the circuit. An instrument of this class can also be made to record the varying values of the power, and is then called a *Recording Wattmeter*.

Electrolysis.—*See* **Electric Tramways.**

Electro-Magnet.—An iron core wound with conducting wires carrying current. *See* **Dynamo.**

Electro-Magnetism.—The production of a magnetic field by the current passing in the coils of an electro-magnet. *See* **Dynamo.**

Electrometer.—An instrument for measuring or recording the strength or quantity of electricity in any current.

Electro-Motive Force (E.M.F.).—The force developed in an electric circuit by the equalising of potential which takes place when electric discharge occurs.

Electro-Motor.—An electro-dynamic machine, reversing the functions of a dynamo and converting electrical power to mechanical energy. A synonym for **Electric Motor.** *See also* **Induction Motor.**

Elephant Boiler.—An old French type of horizontal boiler, comprising three boilers connected by four vertical water tubes. The two lower vessels are called *bouilleurs* or heaters, and are much smaller than the upper boiler. The flame passes under the bouilleurs, and returns at one side, and back along the other side under the large boiler, and thence to the chimney.

Ellipse.—The ellipse is one of the conic sections. (*See* **Cone.**) It is a figure contained by a curved line such that the sum of the distances of every point in the curve from two points within the figure are equal. These two points are called foci, *a*, *b*, Fig. 195 (1). A B passing through the foci is the major axis, C D at right angles to, and bisecting A B is the minor axis.

To Construct an Ellipse.—This may be done by special instruments such as the Elliptic Trammel, or the Ellipsograph, and by geometrical methods. In the shops, however, one or other of the following methods is generally used with perfectly satisfactory results. When the two axes are given and are placed so as to bisect each other as in the diagram (1), take the distance A *o*, and with the compasses in D strike the foci, *a*, *b*. Fix a pin or a tack firmly in each point, and with a looped string equal in length to the major axis describe the ellipse as shown in the figure, keeping the thread taut, and the pencil vertical.

Another means of drawing an ellipse of any size is shown in Fig. 195 (2). E 2 is a strip of

wood on which the distance E 1 is half the minor axis C D, and E 2 is half the major axis A B. This, used as a trammel, is then shifted to a number of positions, always keeping the point 2 on the minor axis, and 1 on the major axis. At each new position mark a point at E; on joining these points the ellipse is completed.

No. 3 is constructed by drawing the two circles shown, and from their centres, with distance *a*, striking arcs intersecting at C, D, which give the centres for the curves connecting the two circles. In No. 4, the major axis A B is divided into three equal parts, and from E and F arcs are struck. Centres are then found for curves to connect these arcs with C and D.

When the major axis is given; divide the length into four equal parts, No. 5, and from 2 as centre, with radius 2-4, and *vice versa*, strike curves intersecting at A and B. From points A and B draw lines through 2 and 4. With 2 as centre, and radius 2-1, describe the curve C E, and from 4 the curve D F. Then with centre A and radius A D describe curve D C, and from B the curve E F.

To describe an ellipse within a rectangle, No. 6 (or when both axes are given). Draw a diagonal B D; take the distance A E on the major axis, and transfer from B to 1 on the diagonal B D; also transfer the distance E D to the point 3. Take half of 1-3 in the point 2 as centre, and any distance towards B greater than its half, and *vice versa*. From B and 2 describe arcs intersecting at 4 and 5, through these points draw a line until it cuts the minor axis at C; make E*a* equal to E*b*, and E C equal to E D; from C and D draw lines through *a* and *b* indefinitely; then with centre *a* and radius *a*A describe the curve 6A8, and from centre *b*, 7B continued; then from centre C and radius C D draw the curve 8D continued, and from centre D the curve 6C7.

To find the Area of an Ellipse.—Multiply the product of the two diameters by ·7854. If D and *d* are the major and minor axes respectively, then area = ·7854 × D × *d*.

To find the Circumference of an Ellipse.—No exact rule exists. The following gives a result near enough for practical purposes:—Multiply half the sum of the two axes by 3·1416. Or

$$\text{circumference} = \frac{D + d}{2} \times \pi.$$

Elm (*Ulmus*).—A hardwood, with some of the characteristics of ash. The elm tree is very common in Britain and also in most parts of Europe and America, though there are a number of varieties. Its dry weight is from 35 to 52½ lb. per cubic foot. It is a tough wood, darkish brown in colour, with fibres coarse in appearance and of a curly interwoven character, rendering it troublesome to work and liable to warp badly, but not easily split in driving nails or boring holes through it. It is very suitable for work under water, such as piles, being an extremely durable wood if constantly wet, but for work exposed to the air its reputation is not high. It is used for the naves of wheels, for pulley blocks, and often for packing cases for machinery and hardware.

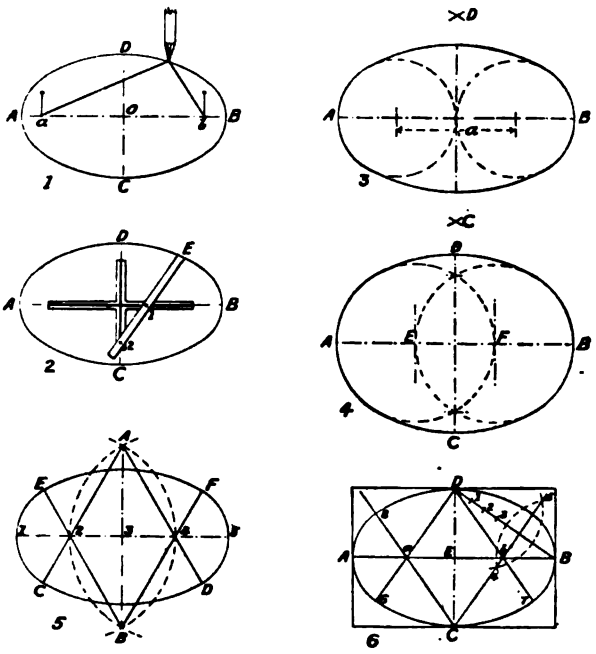


Fig. 195.—Construction of Ellipse.

Elongation.—The stretch of a material or structure under test. Its amount is a measure of ductility, and is of value as giving warning before fracture.

Emery.—Emery is an impure variety of corundum, occurring chiefly in amorphous masses. The principal source is the island of Naxos, lesser quantities being found in other parts of the world. It is employed in a large number of trades for abrasive purposes, in the form of powder, paper, wheels, rollers, blocks, and sticks &c. The powders are graded in a number of sizes, according to the mesh of sieve through which they will pass, and the two varieties classify themselves into Corn and Flour emery. The coarsest corn is used for rough grinding and cleaning, and the finer grades for polishing preparatory to the use of flour, which is suitable for the more delicate work. This also is produced in many grades. These various powders are employed on cloth, paper, tapes, and bands for polishing purposes, either by hand or by machine. The cloth is used on Disc Grinders, and the tapes and bands on polishing machines for cycle work, brass fittings, &c. Grades are varied to suit the class of work done. Blocks and files, consisting either of solid emery or of wood covered with emery, are used largely for finishing and polishing work, including that which is hardened.

Solid emery wheels, made by uniting the grains of loose emery with a suitable bond, are used extensively in all classes of grinding, both of work and tools. There are three processes of manufacture; by mixing the emery with vitreous clays and other silicious and alkaline materials, formed in moulds and then burned in a kiln; by mixing emery with cohesive substances and pressing hydraulically; by mixing with a mineral bond, such as silicate of soda, and drying until sufficiently hard.

The first-named, or vitreous process takes the lead, for several reasons, chief among which are the hardness and cutting properties of the bond, and its ability to withstand water, oil, and acids. In making the vitrified wheels, the grain emery is mixed with vitreous potter's clay, along with water, and mechanically stirred until thorough mixing is effected. Then the semi-liquid mass is drawn off into suitable moulds, which are taken into a drying room, where the superfluous water is evaporated. After removing from the moulds, the wheels are placed on a kind of potter's wheel, and trued up to shape and size with steel tools, which easily part the soft material. The final hardness is then imparted by baking in kilns at a white heat for several days. Final truing up is done on machines with either diamonds, or steel dressers, the sides, periphery, and hole being turned truly. Nothing now remains but testing, which is done by rotating the wheels at about twice their normal working speed. A guard is placed around during the running, to prevent the pieces flying, should the wheel fracture, which sometimes happens.

The shapes in which emery wheels are made will be found under **Grinding Wheels.**

E.M.F.—Electro-motive force. The unit of E.M.F. is the volt, and represents the difference of potential which will cause a current of one ampère to flow through a resistance of one ohm, or the rise of potential induced in a conductor by its cutting 100,000,000 magnetic lines of force per second.

Encastre.—Signifies the case of a beam firmly fixed instead of merely supported at one end.

Enclosed Arc Lamp.—An arc lamp in which the arc is formed in an enclosed globe. *See* **Arc Lamps.**

Enclosed Motor. — An electric motor having its moving parts and windings enclosed in a gas-tight case, the end of the shaft only projecting. Such motors are used in outside situations or in mines, and can be built to run under water if necessary. Totally enclosing the motor, reduces its efficiency by at least 25 per cent., so that it is usual only to cover them, leaving ventilation grids in the case. They are then called *protected*, or *enclosed ventilated* types.

Endless.—A term used to denote a looped form of object, as endless chain or rope. An endless saw is a bandsaw. An endless screw is a worm.

End Measure.—There are two types of end measures used in the workshops, one with spherical ends, employed for testing bores, the other with flat ends for ordinary work. They are either plain round rods in the first case, sometimes with an encircling vulcanite handle, to avoid changes due to the warmth of the hand, or of square or oblong cross section in the second. The latter are used either for direct

measurement, or for setting and testing calipers, and gauges, or on machine tables, for adjusting scribing blocks, or tool points thereto. The degree of accuracy in finish depends on the class of work, the finest being guaranteed to within one 50,000th of an inch.

Endosmose.—*See* **Diffusion.**

Endo-thermic, Exo-thermic. — When chemical action takes place between bodies, an evolution, or absorption of heat occurs. The evolution of heat is termed an exo-thermic action and is denoted by a positive sign +. If heat is absorbed the action is termed endo-thermic and the action is denoted by a minus sign −.

Energy.—The energy of a body is the power it possesses of doing work. This power may be due either to the (1) motion, or (2) position of a body. Thus a pound weight raised a foot from the ground has a foot pound of energy stored up in it available for use whenever the weight falls again to the ground. This energy due to the position of the weight is called *potential* energy. On falling to the ground this energy of rest is changed into an energy of motion capable of overcoming resistance and doing a foot pound of work. This is called *kinetic energy*. The raised steam hammer or pile driver ram are illustrations of potential energy and of kinetic energy when in the act of descending. In an oscillating pendulum both forms occur successively. *See* **Accumulated Work.**

A great and important law is that known as the conservation of energy, which states that the total amount of energy in the universe is constant, and that man is neither able to create nor to destroy energy. He may only convert it from one form into another. Therein lies the work of the engineer, for it consists in continually contriving, designing, labouring to convert one form of energy into another and more useful form. In the process of conversion a greater or less fraction of the energy supplied is lost in overcoming resistances. But the fraction is never destroyed, it is converted into another form useless or even inimical to the engineer, as in the heating of bearings owing to friction. As a matter of fact all forms of energy very readily become converted into heat, and so, as Lord Kelvin pointed out, there is a tendency for all available energy to become converted into one kind difficult to transform into mechanical work.

The engineer is much indebted to the sun for his supplies of energy. But for the process of evaporation the enormous amount of stored-up energy at Niagara would be non-existent. Here, and wherever power is obtained from waterfalls, the electric car, electric light, and the driving of machinery may all be ascribed to the sun's rays. Wind power, too, is indirectly derived from the sun's heat, and coal was formed in past ages by solar light and heat.

The heat obtained from the combustion of fuel, and electrical energy are the two forms best suited for conversion into mechanical work. The relation between mechanical energy and heat produced was established by Dr Joule, who found that the heat necessary to raise one pound of water through 1° Fahr. was equal to 772 foot pounds of work. This is designated the British Thermal Unit. The unit of electrical power is the kilowatt (1,000 watts). One watt is the amount of electric power of a current of one ampère flowing under a pressure of one volt. One horse power is about three-quarters of a kilowatt, since 746 kilowatts = 1,000 HP. A kilowatt maintained for one hour is the unit adopted by the Board of Trade, and electric energy is thus expressed in kilowatt-hours.

Engine Beds.—These are mostly of cast iron, some of the largest chiefly excepted. The advantage of casting is rigidity of the bed, and the casting of most or all of the bearings in one with the bed body, with the further advantage of tooling them in the solid. In the smaller engines having bored guides these are cast with the bed; and the cylinder, which overhangs, is generally bolted to the end of the guide. To increase rigidity the top of a bed is often plated over as far as possible, the recess for the sweep of the crank being solid-plated, and curved, so helping to tie the sides together, besides catching the waste oil.

There are two variations in the forms of beds due to the use of a dip crank, or a disc crank. The former is symmetrical about the longitudinal centre line, and has two crankshaft bearings; the latter has but one bearing cast with the bed, and forms the *bayonet* pattern.

As engines increase in size the beds become more girder like in form, that is the length is increased more rapidly than the width. A good many large engine beds are built up mainly of joists, with the bearings bolted on. A good foundation is necessary for engine beds, and the lugs for the hold-down bolts must be deep and stout.

Engine Efficiency.—The efficiency of a steam or other engine is twofold, viz, mechanical and thermodynamical. By the mechanical efficiency is meant that proportion of the power, actually produced by the working fluid, which can be extracted from the point of delivery. Thus the gross or Indicated Power of a steam engine is the amount of energy or work which is represented by the average pressure on the piston multiplied by the distance travelled by that piston in a unit of time. Thus, say a piston has an area of 100 inches, and an average pressure of 33 lb. per square inch upon it, and it travels 600 feet in one minute. Then the Indicated Power of a double-acting piston is $100 \times 33 \times 600 \div 33{,}000 = 60$ HP., for 1 HP. is equal to 33,000 foot pounds per minute. The friction of the piston and of the valve, crank pin, main bearings, crosshead, glands, and the atmospheric resistance to the flywheel absorb some of this power. Let this absorption be, say, 6 HP. Then the net HP. is 54, and this is 90 per cent. of 60. Hence the mechanical efficiency of the engine, as a piece of machinery, is said to be 90 per cent. The best engines may work as high as 94 per cent. Poorer engines, especially if underloaded, may not show more than 70 to 80 per cent.

Approximately the friction of an engine is independent of the work it is performing, or at least it does not increase nearly in proportion to the mean pressure. This fact is one of the factors which puts an early limit upon too great an extension of the principle of expansive working; for if an engine with a mean pressure of 40 lb. per square inch be made to give half its power by more expansive working to a mean pressure of 20 lb. per square inch, then the frictional loss will be of double ratio. For where the highly loaded engine of 100 I.H.P. gave 90 brake or net HP., the half-loaded engine of 50 I.H.P. would only give 40 B.H.P., or an efficiency of only 80 per cent., which would go a long way towards diminishing the gain due to the increased expansion, if indeed it did not reverse such gain and show an actual increase in the weight of steam per B.H.P. Other factors contribute to render useless high rates of expansion, and one of these is the phenomenon of cylinder condensation.

But closely connected with mechanical efficiency is the commercial efficiency of an engine. If an engine is made very large in order to secure a high degree of expansion, not only must the economy derived from expansion pay for the loss of mechanical efficiency, but it must pay for the interest, depreciation, and rent charges which must be incurred on account of the extra capital cost of the bigger engine, and it must pay for any extra charge in attendance, and lubrication, and stores generally. The highest commercial efficiency is therefore only to be obtained when an engine uses more steam per B.H.P. than it would do if cost were of no importance, and more again per I.H.P. At the same time a set-off in favour of the larger and more economical engine may be partially secured by the saving effected in boilers and accessories. Gas engines have a higher mean pressure per working stroke than have steam engines, and are thus far of higher mechanical efficiency, but they have fewer working strokes and thus tend to have a lower mechanical efficiency. A double-acting gas engine with one cylinder has only half the working strokes of a similar steam engine, but it may have 50 per cent. more mean pressure, and for a given size will produce only 20 to 25 per cent. less power per revolution. Gas engines, as machines, are not less efficient, except that the necessary cycle reduces the use factor of the cylinder volume, and flywheels must be heavier, whereby bearing friction is increased.

By the thermodynamic efficiency of an engine is meant that ratio of the power potential in the working fluid that is converted into work. It is usual to adopt as a comparative formula the equation, $E = \frac{T_1 - T_0}{T_1}$, where E is the efficiency, T_1 is the absolute temperature of the steam entering the cylinder, and T_0 = the temperature

of the steam at exhaust pressure. No engine can give an efficiency higher than this formula shows. All give less. E is the ratio of the heat value of the work of the engine to the heat value of the fluid supplied to it. The real efficiency of the engine may be stated as the ratio of the actual efficiency to the theoretical efficiency E. Thus, let the heat supplied be 100, and E be found equal to 10 for any given case. Then the thermodynamic efficiency is 10 per cent. Let the heat value of the work done be 7, then the real efficiency is $\frac{7}{10}$ or 70 per cent. It is usual to say that the best engines are very inefficient because they convert too little of the heat value of the fuel into work, but this is incorrect, for they do convert into work a large portion of the heat energy which it is possible they can convert, and the datum line of comparison must not be taken as the total heat added to the steam by the fuel, but as the fraction E of such total heat which the perfect or theoretical engine can convert.

The thermal efficiency of a steam plant as a whole may be variously stated. Thus an engine discharges 80 to 90 per cent. of the heat supplied to it, by way of the exhaust steam, and much of this heat may be employed to warm the feed water for the boiler, and such recovered heat adds to the thermal efficiency, which for the whole plant may be taken as the ratio of the heat value of the engine power to the calorific capacity of the fuel. Thus an engine works with $1\frac{1}{2}$ lb. of coal per B.H.P. This work represents 2,565 heat units. The value of the coal is, say, 21,000 heat units. Then the overall efficiency of the plant would be about $12\frac{1}{4}$ per cent., and such a high efficiency would only be secured by means of waste heat feed heating, and every possible care and attention to combustion of fuel and use of steam. *See* **Feed-Water Heater, Superheating,** &c.

Engineering.—This is of so wide a scope nowadays that the word conveys no specific meaning, unless qualified by a prefix, as mechanical, civil, electrical, hydraulic, pneumatic, railway, mining, &c. The day is long past when one man could cover the whole range of engineering, two, or three branches only being within the capacity of the average engineer. Although the various subdivisions give rise to specialists, the interdependence of the different classes necessitates a good general knowledge on the part of the leaders of engineering. In the civil branch, for instance, the enormous quantity of machinery and appliances employed renders a good knowledge of mechanical engineering essential, and the same applies to electrical and other work.

The theoretical and the practical sides of engineering both have their adherents, but the best results are attained by a judicious blending of the two, experience and trial correcting the mistakes made in initiative work. The present volumes contain both theory and practice in appropriate proportions.

Engineers' Stores.—*See* **Stores.**

Entablature.—*See* **Architrave,** and Fig. 126, p. 175, Vol. I.

Entasis.—The curvature lengthwise on a bellied column.

Entropy.—A term due to Clausius to denote the same thing which Rankine termed the "thermo-dynamic function." It signifies a property of a body which remains constant so long as there is no communication of heat to the body, but which increases or diminishes respectively when heat enters or leaves the body. *See* **Thermo-Dynamics.**

Epicyclic Trains.—Trains of gear wheels in which besides the motions of the wheels around their axes, one or more has a motion of translation round one with a fixed axis. Such a train is a kinematic chain with one link—the stationary wheel, fixed.

In Fig. 196, let A in the upper diagram be a fixed wheel, and B one revolving round it, both of the same diameter. It is clear that if B were to rotate and carry A with it, both turning round the centre *a*, there would be no movement arising from engagement of the wheel teeth. But if B is rotated round A, A being fixed, B will make one complete revolution on its axis *b*, though A will remain fixed on its axis *a*. If now A be rotated once, and at the same time B is rotated round it in the same direction, B must make two revolutions round its axis. In the train of three wheels in the second diagram, C being an idler, and A and B equal, the wheel B will turn once in the same direction as the arm is rotating. But it will also turn once in the opposite direction to that

of the arm, by reason of the insertion of the intermediate wheel C. Hence B will be carried round A, without moving round its own axis. The motion of B is therefore one of translation only, and not of rotation. Hence the general rule applicable to gears of this class:—The number of revolutions of the last wheel on an epicyclic train for each revolution of the arm, equals one, plus the velocity ratio of the train, if the number of axes is even (as two, four, &c.). It is one minus the velocity ratio, if the number of axes is odd (as three, five, &c.). It shows

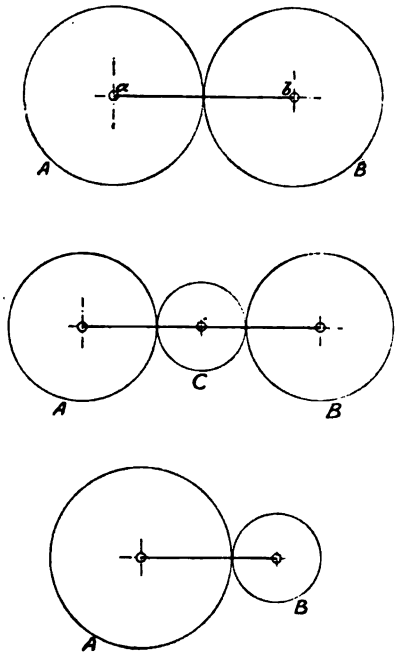


Fig. 196.—Epicyclic Trains.

that in a train, or a pair, the velocity ratio is different from that which appears to be due to the diameter of the wheels. If wheel B, as in the third diagram, is half the diameter of A, it will, in rotating round A, revolve twice by reason of its tooth relations to A, and once by reason of its rotation round A = three revolutions.

Epicyclic trains occur in many mechanisms, in the power capstan, in the old sun and planet wheels, in boring bars, and in combinations of bevel wheels, as in a system rotating round a fixed bevel wheel. The wheels A B may be used directly to feed a boring bar, the smaller wheel B being attached by a fixture to the poppet centre, and the large one to the end of the feed screw. In such a case A would have to be very much larger than B to impart a feed sufficiently fine.

Equal Forces.—If two forces acting on a body in opposite directions balance each other, and so maintain the body in a state of rest; or if when applied to a body for equal intervals of time, these forces impart to it the same velocity or change of velocity, they are said to be equal forces.

Two equal parallel forces, acting in opposite directions, but not in the same straight line, produce a *couple*.

Equality of Moments.—*See* **Moments.**

Equations.—For lack of a little knowledge of algebra, the realm of theory is, to a large extent, closed to the practical engineer. On the threshold of such important subjects as force, friction, velocity, elasticity, strength of materials, he is confronted with repulsive looking formulæ which, by mysterious processes of mathematical juggling, are made to reveal all manner of (theoretical) truths concerning the quantities involved.

In reality the process of transferring terms from one side of an equation to the other so as to isolate one required quantity is a simple process, and is based on the following rules:—

1. Any term of an equation may be transposed from one side of the equation to the other if the sign be changed.

2. If every term on each side of the equation be multiplied by the same number, the results are equal. Similarly, every term on each side may be divided by the same number without affecting the equality.

The truth of both these rules is self-evident when ordinary numbers are substituted for abstract quantities. For if $24 = 16 + 8$, then by the first rule $24 - 16 = 8$, and $24 - 8 = 16$, the signs of the quantities (16 and 8) transferred to the other side being changed in accordance with the rule. Examples illustrating this process are found in the equations dealing with **Acceleration.** $V = V_1 + AT$, where V_1 is the initial velocity, V the velocity after T units of time, A the acceleration. To find the actual increase of velocity it is necessary to transfer

V_1, the initial velocity, to the left-hand side of the equation, changing the sign, $V - V_1 = AT$.

If the body starts from rest, then $V = AT$. Here there are no plus or minus signs, and the transposition of the terms follows the second rule. If the values of V and A are given, and T is to be found, divide both sides by A. Then $\frac{V}{A} = \frac{AT}{A}$. Eliminating the A's on the right-hand side by **Cancellation**, $\frac{V}{A} = T$, or $T = \frac{V}{A}$. Again, dividing both sides by T: $\frac{V}{T} = \frac{AT}{T}$, or $\frac{V}{T} = A$, or $A = \frac{V}{T}$. Really this amounts to changing the sign on transposition, for a term which is a multiplier on one side becomes a divisor on the other, and *vice versa*. If $24 = 8 \times 3$, then $\frac{24}{8} = 3$, and $\frac{24}{3} = 8$. In questions involving toothed wheels, $n = \frac{\pi \times d}{p}$; where n = number of teeth; d = pitch diameter in inches, p = pitch of teeth. Let the divisor p on the right become a multiplier on the left (or what is the same thing, multiply both sides by p); then $n \times p = \pi \times d$. From this $p = \frac{\pi \times d}{n}$ and $\frac{n \times p}{\pi} = d$, or $d = \frac{n \times p}{\pi}$.

In some equations the sign of the square root occurs, and has to be eliminated. This is done by squaring both sides of the equation. A concrete example shows at a glance that this process does not affect the result; $12 = \sqrt{9} \times 4$; squaring both sides, $144 = 9 \times 16$. Let it be required to find the value of h (height), in the well-known formula for falling bodies, $v = \sqrt{2gh}$. Square both sides, $v^2 = 2gh$, and transpose $2g$ to the opposite side. $\frac{v^2}{2g} = h$, or $h = \frac{v^2}{2g}$. Conversely, it may be necessary to extract the square root of each side. In questions concerning the simple pendulum the equation $t^2 g = \pi^2 l$ occurs. Here, $t^2 = \frac{\pi^2 l}{g}$, $\therefore t = \pi\sqrt{\frac{l}{g}}$. In an unloaded Watt Governor, $n^2 = \frac{900g}{\pi^2 \times h}$. Taking the square root of each side $n = \frac{1}{\pi} \times \sqrt{\frac{900g}{h}}$. Here, π must not be included under the sign $\sqrt{}$ as its square root has already been taken, yet it must remain a denominator, and so it is given the numerator 1. The equation becomes a trifle more complicated in the loaded governor.

$$h = \frac{900g}{\pi^2 n^2}\left(\frac{W + w}{w}\right).$$

$$\therefore n = \frac{1}{\pi}\sqrt{\frac{900g}{h}\left(\frac{W + w}{w}\right)}.$$

Occasionally two equations are multiplied together, or one divided by the other. Thus $V = FT$, and $S = \frac{VT}{2}$. Multiplying, $VS = FT \times \frac{VT}{2}$ or $VS = \frac{FVT^2}{2}$. $\therefore S = \frac{FT^2}{2}$, for V may be eliminated as it is a factor of both sides, just as 3 could be eliminated in $3 \times 8 = 2 \times 4 \times 3$ without altering the state of equality between the two sides of the equation.

Equilibrium. — Etymologically this term means the state of being evenly balanced. In statics, forces are said to be in equilibrium when their action is such that the body on which they act tends to change neither its state of rest nor of motion. It is important to note that equilibrium does not always imply rest. A boy's top, a bicycle, or a motor car, as long as they travel with uniform speed, are just as much in equilibrium as a boulder on the seashore. The former are cases of *kinetic* stability, the latter *static* stability.

Bodies at rest under the influence of gravity may be in one of three states of equilibrium according to the relative positions of the centre of gravity of the mass, and the point of support.

(*a*) *Stable Equilibrium.*—In this case the body, when disturbed by another force, tends to return to its original position. The pendulum is a common example. In such cases, the centre of gravity is *below* the point of suspension.

(*b*) *Unstable Equilibrium.*—In this case the body, when acted on by another force, does not return to its original position, but recedes further from it. Example, a cone balanced on its apex. In this case the centre of gravity is *above* the fixed point, and the weight of the cone tends to pull it down.

(*c*) *Neutral or Indifferent Equilibrium.*—Here a disturbance of the body cannot alter the

position of the centre of gravity. A billiard ball, when moved, remains equally at rest in any new position. The centre of gravity of a sphere is at its centre, and obviously no movement can either raise or lower it.

Equilibrium Slide-Valve. — *See* **Slide-Valves.**

Erecting.—The section of engineering in which the heaviest motors and mechanisms are put together and completed. Often the fitter is also the erector, but frequently the first named prepare the smaller sections, which are then passed on to the erector. Erecting is generally too massive to be done on the bench, though the bench and its vice are essential for making corrections of parts on. The erecting of any shop is work peculiar to that shop. It differs in many respects in a crane shop, and a marine, or locomotive, or pump, or refrigerating, or mining works. But in principle similar methods have to be adopted; as levelling, plumbing, centring, scribing; the use of parallel straightedges, of straining lines, of gauges, of squares, &c. For in large erecting, distances are too great to be measured from one another by direct means, or they are in different planes, hence the reason for the adoption of these geometrical devices, which also have some resemblances to those of the marker off.

Erecting Shop.—A shop or shed in which work of the erector is done. Much of the largest kind cannot be done in a roofed shop, but must be erected in the open yard.

The equipment of the erecting shop comprises vice benches, a large quantity of timber blocking and wedges for levelling up work upon; lifting tackle suitable for the class of work done, as overhead travelling cranes, swing cranes, pulley blocks, screw and hydraulic jacks, ropes and slings, and sling chains. Out of doors, Goliath cranes are used, or bridge cranes. In many shops pits have to be sunk, in or over which work is erected, either because of its great height, as in marine engines, or because of the amount of adjustment that has to be done from below, as in locomotive erection, and in some steam crane work, or for the purpose of testing, as in electric travellers.

The work of the fitter has been largely invaded by the methods of the interchangeable system; that of the erector is practically unassailable. The massive character of the erections renders hand work continually essential, for obviously a few heavy machines cannot be manufactured by the same methods as large numbers of small ones. Fig. 197, Plate XIV., gives an illustration of a modern shop in which fitting and erecting are included. Fig. 198, Plate XIV., shows a traction engine erecting shop.

Erg.—The C.G.S. unit of work or energy expended in moving a body against a resistance of one dyne in one second.

Escape Valve.—Any valve which permits the escape of a liquid or a gas when the pressure exceeds a pre-determined amount.

Estimating.—Getting out the cost of work for the purpose of tender. To base prices for new orders on that of similar work previously done is only safe when no circumstances have occurred to vary the cost of production, or of materials. The introduction of new machinery and of different shop systems often effect great variations in prime cost.

Properly the work of estimating is divided between the managers and foremen in the shops, and the clerks in the office, who are generally specialists—*estimating clerks.* The case is very different in shops dealing with single pieces of massive work, and those which handle large numbers of small articles. The costs in the first will not fluctuate nearly so much as they do in the second, because of the great economies which may be effected by the preparation of special tools and appliances in the latter. Moreover, the cost of these can be fixed almost exactly by giving out a trial number of pieces, and noting the time occupied. In some departments, as in the foundry and boiler shop, tonnage is made the basis of prices; and this, even though the cost may have been reckoned out in time previously per piece. For instance the cost of moulding a casting may have been estimated, or ascertained, and on that is based the price per ton of similar castings. In the machine shop and turnery prices are mainly governed by the pace of the machines, and by the aids available from jigs, and appliances, and special tools. But even then the human element may not be ignored, some highly specialised



Fig. 197.—Erecting Shop for Heavy Machine Tools. (Kendall & Gent, Ltd.)



Fig. 198.—Erecting Shop for Traction Engines. (J. & H. McLaren.)

To face page 210.

cases apart, because different men take longer or shorter periods in fixing up.

The estimates of one firm are not readily comparable with another doing even the same class of work, due to differences in shop conditions; and where day work is the rule and the body of men of a fluctuating character, it is quite necessary to add a considerable percentage for contingencies: this may range from 5 per cent. to 20 per cent. It is better to over-estimate a little than to run risk of loss.

The foregoing relates to labour estimates only. To these have to be added, in the office, the cost of materials at current rates, the charges for the use of machinery, the salaries of the staff, shop expenses, depreciation, and other expenses, for which *see* **Accounts—Factory.**

Ether $(C_2H_5)_2O$.—Is a colourless mobile liquid, with a powerful odour; solidifies at $-129°$; sp. gr. ·718. Ether boils at 34·5°, and as the vapour forms an explosive mixture with air, great care is needed in experimenting with this liquid.

Ether is prepared by the "continuous etherification process," in which a mixture of sulphuric acid and alcohol is heated to 140° and a regular current of alcohol then passed through; ether and water are formed.

Eutectic Alloy.—The most fusible alloy in a series composed of two or more metals and in which crystallisation occurs in successive stages. When there is no single freezing point, or points at which an alloy begins to crystallise, the particular alloy that freezes last is termed the eutectic. Few alloys have only a single freezing point, many have three, and some four or five. The eutectic is likened to a fusible metallic *mother liquor*, having its analogy in the mother liquor of a salt solution, which remains fluid after the bulk of the salt has crystallised out.

The composition of these eutectic alloys does not usually correspond with simple atomic proportions. The excess of metal in solution begins to solidify at a temperature at which the solution is exactly saturated. Each solution leaves on cooling a solid deposit, and a fluid metallic mother liquor. These mother liquors do not usually unite with one another. The stronger alloys are more complicated, and have more eutectic alloys than the weaker alloys. In the copper-tin series there are six, in the copper-zinc at least four. *See* **Aich's Metal, Freezing Point.**

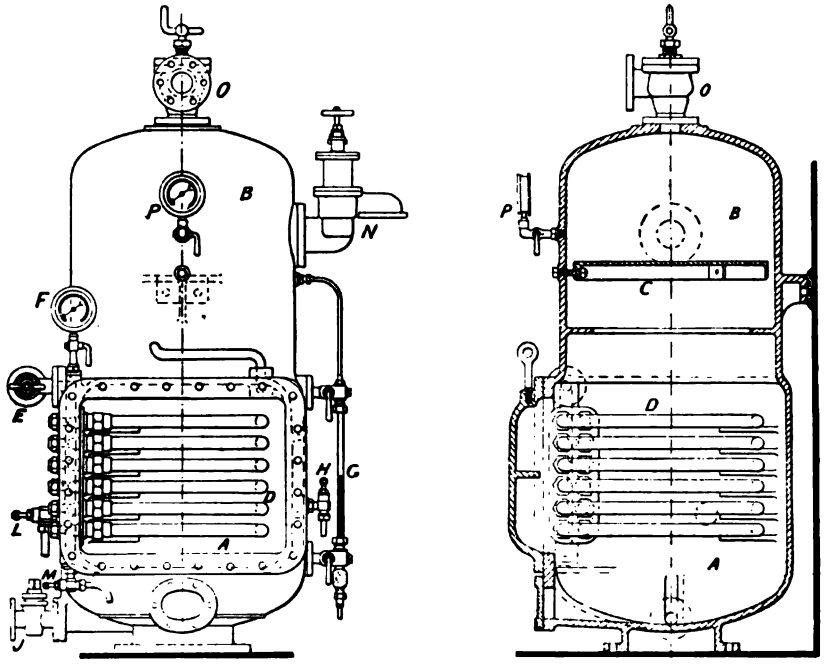


Fig. 199.—Weir's Evaporator.

Evaporation.—Is the process by which a substance is converted into vapour. In a less strict sense the term is confined to this process in liquids. Sublimation is akin to evaporation, and a theory has been propounded that the characteristic smell of many solids is due to the passing off of minute invisible particles from the surface.

The vapour escaping from the free surface of

a liquid exerts pressure, and when a certain vapour pressure (called the point of saturation) is reached, evaporation ceases. In the case of boiling, however, the vapour pressure overcomes this external pressure. The greater the area of surface exposed, the greater is the rate of evaporation. Obviously, also, evaporation will be greater when a current of air removes the escaping vapour than when the air is stagnant. These laws are made use of in commercial processes, such as the evaporation of brine, and the preparation of sugar from syrup in vacuum pans. Heat is absorbed during the evaporation of a liquid, and given out when the vapour is condensed. This heat is called the latent heat of evaporation. Each liquid has its own latent heat.

Saturated vapours do not obey Boyle's law.

Evaporator.—A vessel in which the make-up, or auxiliary feed water required for marine engines is evaporated, the object being to avoid

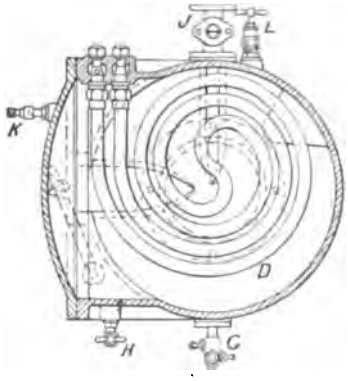


Fig. 200.—Evaporator Coils in Place.

the use of salt sea water. The development of evaporation is due to the increase in steam pressures, and results from the larger weight of water that has to be evaporated, and to the increased scale which is deposited at higher temperatures. The first attempts to remedy the evil were made by carrying a supply of fresh water in double bottoms, or in tanks; but these added to dead weight, and as the water generally contained lime and other salts, incrustation still resulted.

Weir's evaporator (1884) first solved the difficulty. This was of the horizontal type, since superseded by the vertical, not because of any greater efficiency, but of convenience. It comprises, Fig. 199, a lower generating chamber A, separated from an upper steam chamber B, by a diaphragm or deflector C. The heating surface is formed of coils of solid-drawn copper tubes D. The shape of the coils in plan is seen in Fig. 200.

The water to be evaporated is taken from the discharge water from the main condenser, and it is evaporated by live steam from the boiler, passed through the copper coils. There is therefore a system of cocks and gauges necessary as follows:—

The steam inlet valve E to the coils, and having a pressure gauge F. A water gauge G, with top and bottom try cocks. A feed check valve H. Cock for blow off J. Salinometer cock K. Brine valve L. Valve for drain from coils to hot well M. Drain cocks. A safety valve on the steam dome N, a valve for the outlet of the generated steam O, a compound gauge P for generated steam in shell; besides some other details. The outlet steam may be led to the feed heater, or to the L.P. receiver, or to the hot well to heat the feed water; the first being the most economical. The feed pump is usually worked off the air pump levers.

In the latest design of the Weir evaporator shown in these figures, and by the photos; Figs. 201, 202, Plate XV.; each single tube can be taken out separately for cleaning, the threads of the couplings are outside the evaporator, where they are tightened, and cannot become covered with scale, and where any leakage is visible at once. The part of the coupling which takes the strain of fixing is made of specially strong forged manganese bronze, and no strain comes on the copper tube itself. No pipe or flange joints have to be broken when withdrawing the tubes for cleaning, and each tube is supported at the centre as well as at the ends.

An important part of the duty of the attendant is the blowing off of brine about every four hours. This has to be done as follows:—Shut the outlet steam valve, and open the bottom blow-off cock which is in communication with the sea. When the water is all blown out, close the inlet steam valve. The cold feed water will enter, condensing the steam, and

creating a vacuum, into which the sea water will now rush rapidly, through the blow-off cock, which will be shut off when the water shows in the gauge glass. Then the setting of the inlet and outlet steam valves will put the evaporator in working order again. The effect of this sudden change of temperature is to crack the scale off the tubes. This will collect in the bottom of the chamber, to be removed by the sludge hole door before it accumulates sufficiently to reach the tubes.

Evaporators are rated by their production in tons of feed per day. These range from 1 to 60 tons. No exact rule can be laid down for the choice of a given size, but approximately a ton of feed per day per 100 I.H.P. is given; or from 4 to 8 per cent. of the total feed. Larger sizes are more economical than small, and the rating is done on the supposition that the tubes are covered with average scale.

Excavator, or **Steam Navvy**.—The name given to a group of machines that combine a digger with a crane, though the **Grabs** are often so termed. But the excavator is used on land only, while the grabs work in the dry, and below water. In America excavators are commonly termed dredgers, which confounds terms which we apply to submarine operations.

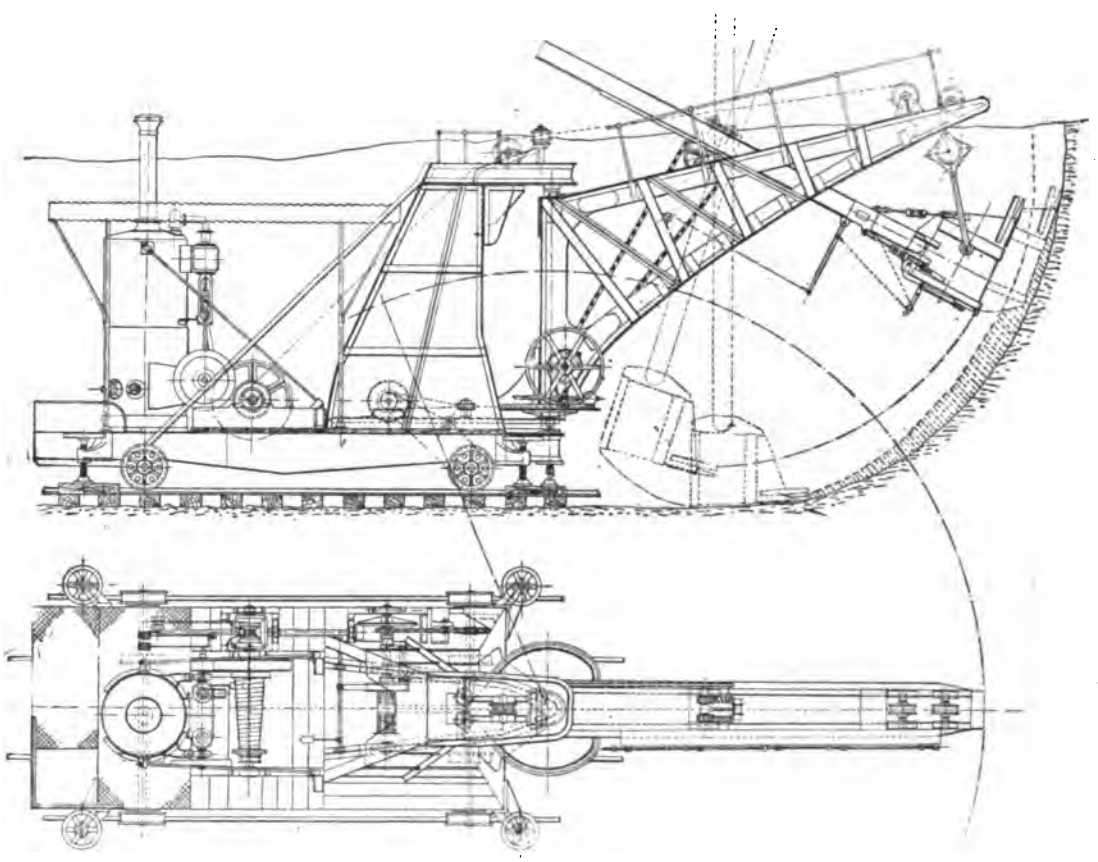


Fig. 203.—10 H.P. Steam Navvy.

One of the best known excavators is the Ruston, illustrated by the drawings, Fig. 203. The crane is built specially stiff, and steel enters largely into its construction. Except that it has the vertical cross tube boiler, and the double cylinder engines, it bears little resemblance to the ordinary cranes. The place of post and side frames is taken by a plated tower, well braced.

The jib is as deep as the tower where the two are attached, and is of the double webbed, lattice braced type. The main or hoisting drum which lifts the buckets is of fusee form. Another drum driven through a third-motion shaft slews the jib. The bucket is of steel plate, and having picks or tines at the front edge for penetrating the soil. These are made of different patterns to suit different soils, and some have detachable shoes of manganese steel.

The bucket is attached to a handle of oak (or metal) strengthened with iron plates, which swings between the jib sides. Its depth of cut can be regulated by a rack and pinion connected by a pitch chain to a hand-wheel, controlled by an attendant located on a platform at the foot of the jib. It is provided with a foot brake. The chains for slewing the jib pass round the platform. The bucket is provided with a door for the discharge of the contents, which is self-closing, but is opened by the attendant pulling a cord.

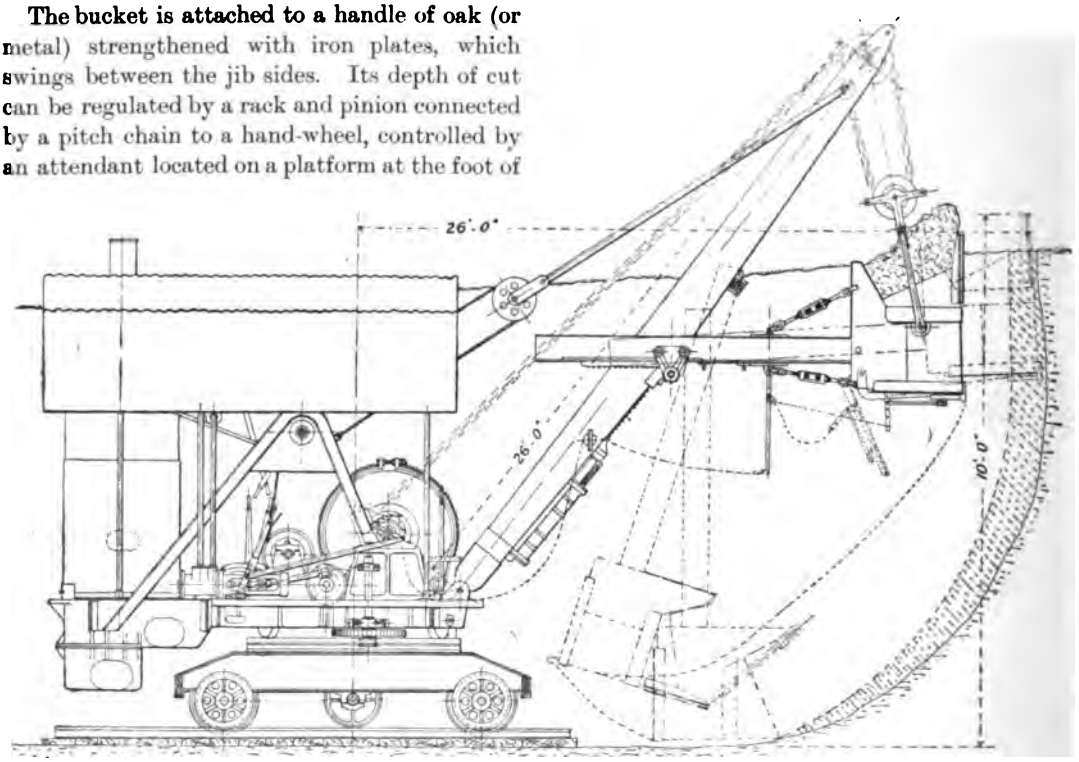


Fig. 204.—12-Ton Steam Navvy.

The machine is worked by lowering the bucket until its handle is in the vertical position, with the crane brought to the face of the cutting. The engine being then started, the bucket is dragged forward and upward into the earth. The depth of cut is regulated by the quantity of material required to fill it by the time it has reached its top position. The jib is then slewed to hang the bucket over the wagon brought up in readiness, and its contents are discharged by releasing the catch of the door. On slewing the jib back for the next cut, and lowering, the door closes automatically.

The best economies are obtained when double track roads for wagons flank a central gullet, first cut by the navvy for its own passage. Working thus, as much as 378 wagons of moderately stiff soil, each holding 4½ cubic yards, have been filled in ten hours. An average of 300 to 350 wagons should be obtained. With one track or side road only, the output is somewhat less. Generally the rapid handling of wagons is of most importance, since the excavator will make from 80 to 120 cuts per hour.

Figs. 204, 205 show another type of navvy, the "crane" style, using a jib resembling that of an ordinary crane, fitted with a cylinder

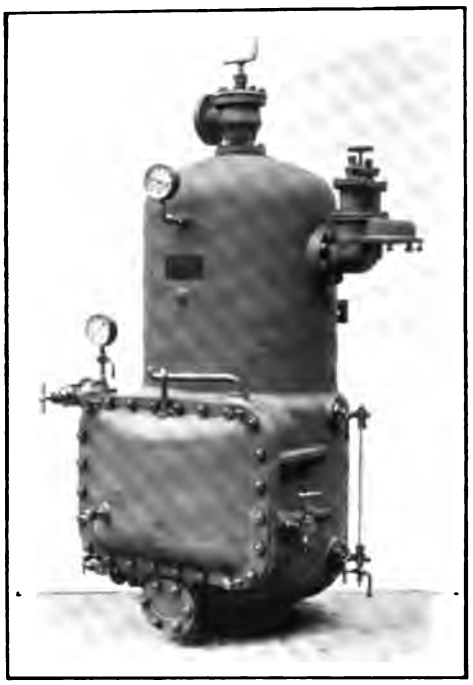


Fig. 201.—Weir Evaporator.

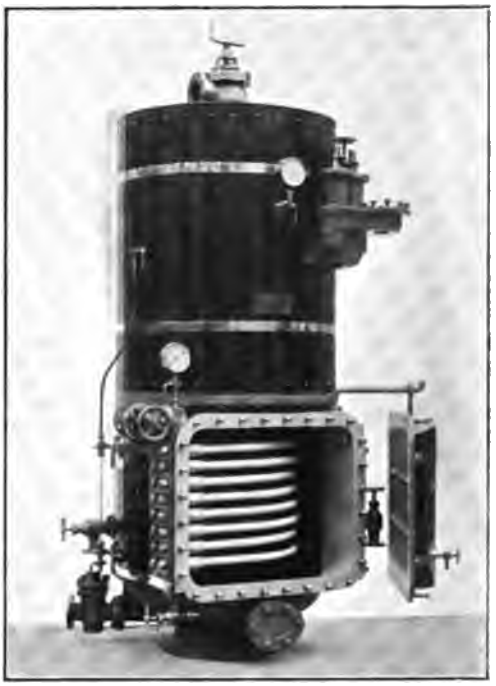


Fig. 202.—Weir Evaporator, Cleaded.



Fig. 206.—Ladder Excavator. (Ruston, Proctor, & Co., Ltd.)

To face page 214.

working a rack, by which the bucket arm is actuated—Ruston's patent bucket-gear. Fig. 205 is an enlarged detail of this, in which A gives a section through the jaw and arrangement of bucket, and B an elevation of the triangular rocking arm, while C shows a section through the rocking shaft. The drawings are self-explanatory.

The photo, Fig. 206, Plate XV., shows a ladder excavator by the same firm. It comprises a ladder pivoted at its upper end, which can be raised or dropped at its lower end to any required angle to suit the cutting slope. The ladder is constructed of two channel irons, braced together, in which runs a trolley that forms the back of the bucket. The chain is attached to the bucket, and therefore the resistance of the material being excavated to the teeth of the bucket, is met directly by the chain, while the ladder keeps the bucket firmly to its work. The bucket is of ½ cubic yard capacity, and the work of filling, emptying, and lowering is performed in about forty seconds. The ladder is operated by a small independent engine. After a number of cuts have been taken, and the working face approaches the front wheels the machine is traversed a distance equal to the width of the bucket to take another series of cuts. A similar style of machine is constructed for making trenches.

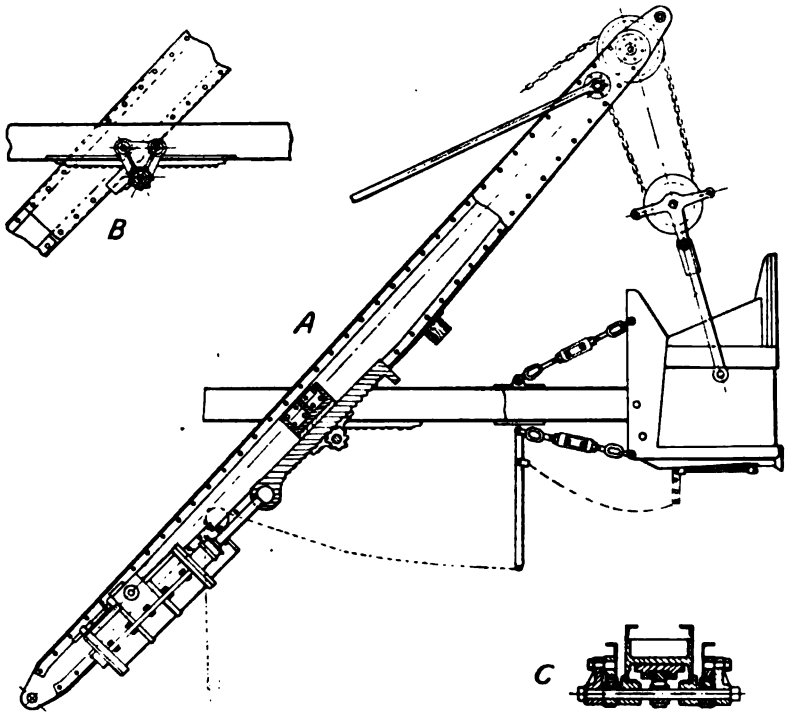


Fig. 205.—Detail of Bucket Gear.

Exciter. — A continuous current dynamo used for exciting the field of an alternator.

Exhaust.—Signifies generally the escape of steam from an engine after it has done its work. It escapes to the air, or to the condenser, or to another cylinder (low-pressure), or it is utilised in a feed-water heater. The edges of a slide-valve by which the steam escapes are the exhaust edges. Exhaust lap is that amount of lap by which ports are prematurely closed to cause compression or cushioning of the steam. An exhaust line is the bottom line of an indicator diagram. The exhaust port, and pipe respectively are the passages by which steam escapes. An exhausting fan is an ordinary fan having the sides enclosed.

Exosmose.—*See* **Diffusion.**

Exo-thermic.—*See* **Endo-thermic.**

Expanded Steel.—Steel that is pierced and opened out, giving spaces of lozenge or diamond shape, which may be filled and covered with concrete, give one type of armoured construction that is of high value in nearly all kinds of building construction. *See* **Armoured Concrete.** It is the invention of John F. Golding, 1889, but the process as at present carried on is a vast improvement on the original. The machine used, Fig. 207, Plate XVI., comprises a lower stationary shear blade,

and a top series of blades, crank driven, with corrugations, representing half the sizes and forms of the meshes longitudinally. The sheet metal is fed forward to the cutters, and sideways between each stroke, and the machine cuts, slits, and stretches the metal into a meshwork.

The dimension across the short way of the diamond is that by which sheets are specified, as $\frac{1}{4}$ in., $\frac{3}{8}$ in., 3 in., or 6 in., &c. Each mesh is made in different weights corresponding with sheets of different thicknesses. 3-in. mesh is that commonly used for armoured concrete construction. The area of steel in section in proportion to concrete is as 1 : 200, or $\frac{1}{2}$ per cent. Thus 3-in. mesh, $\frac{3}{16}$ in. by $\frac{1}{8}$ in. strand is suitable for 3-in. concrete; 3-in. mesh, $\frac{1}{4}$ in. by $\frac{1}{8}$ in. strand for 4-in. concrete; 3-in. mesh, $\frac{3}{8}$ in. by $\frac{3}{16}$ in. strand for 9-in. concrete.

The expanded metal in being cut and opened is forced to assume a form that is not perfectly flat, but in which the sections take an angular position. The result is that when laid down, the sheets only touch at one point in each mesh, and when the concrete is applied it works around and beneath the metal (see Fig. 208, Plate XVI.), embedding the latter, yet leaving it close to the lower surface, where being in tension it occupies its most efficient position. More than one layer is used where extra strength is required.

More than 1,000,000 square yards of expanded steel were used in the Paris exhibition of 1900. Large quantities have been used in many classes of structures.

An example of the application of expanded metal and concrete is seen in Fig. 209, Plate XVI. It is a cover for a reservoir being laid upon columns and girders. The metal is clearly seen down the centre of the picture, and the concrete thickness on each side. Sewers are also constructed thus, employing sheets of metal 8 ft. by 9 ft. 6 in.

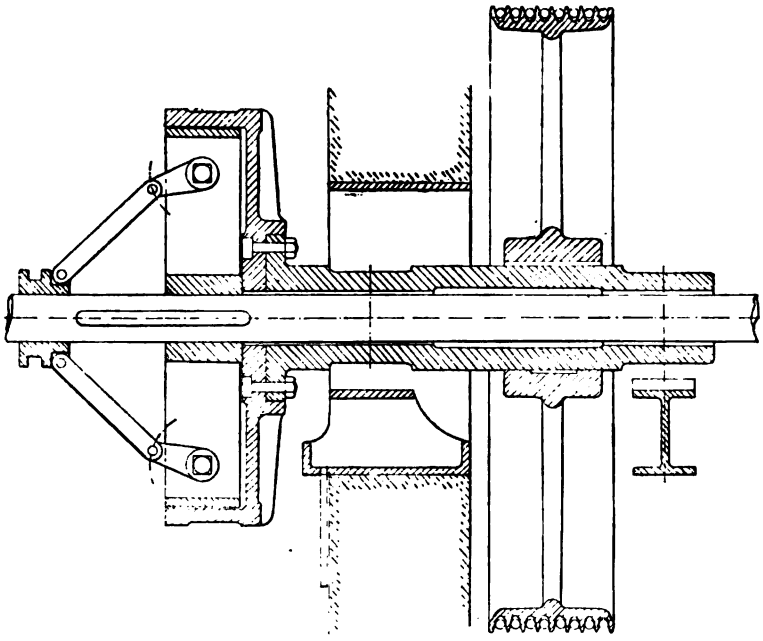


Fig. 210.—Expanding Clutch.

Expanding.—The term has many applications besides those treated in adjacent paragraphs. Expanding drums have movements of cones or other devices by which diameters for the reception of belts are varied. Expanding mandrels, or reamers, or taps, are those in which slight adjustments can be made for diameter, and will be found treated under **Mandrel, Reamers,** and **Taps** respectively.

Expanding Bit.—*See* **Bit.**

Expanding Clutches.—Clutches which, not being coned, cannot be slid into engagement in an endlong direction. They must therefore be moved radially, and so must be elastic, which involves the dividing of the inner ring to permit of forcing it outwards to make frictional con-

tact with the interior of the shell or casing. The methods of expanding the ring may be classed broadly as the wedge, and the lever, both of which are diversified in detail.

In an expanding clutch using a wedge the wedge is operated by a pivoted key which is pushed up against the wedge by the sliding of a cone along a feather key on a shaft.

A good expanding clutch is that by David Bridge & Co., Fig. 210. Here the movement is by means of levers put into motion by the sliding of a boss along the shaft. The levers operate a right and left hand screw of quick pitch, which forces the split ring outwards into frictional contact with the casing. Given the element, the applications are numerous. These clutches are made in three types:—For shafts by which dynamos or shafting can be connected and disconnected; for pulleys or wheels for transmission of motion; and for main drives from engines and motors.

Expanding Tool.—A tool used for expanding, or for expanding and beading tubes in their plates, and ferrules in the tubes. The simplest tool is one like Fig. 211, A, driven with the hammer, and so forcing the tube open; not a very good device, but still employed. Beading is also done by hammering, B, and this is commonly adopted. But the proper tools to use are the roller or mandrel expanders, which exercise pressure only. Of these there are several. The Dudgeon is the best known, Fig. 211, C. It has three loose rollers confined in recesses in the body of the expander, and kept endwise by a plate. These rollers are thrust outwards, and revolved by turning the tapered mandrel. The expander has to be set to a proper depth by means of a set screw, and the mandrel is tapped with a hammer to tighten it before being turned, and this tapping is repeated between each turn until the tightening is complete. Some expanders are self-feeding.

Expansion.—Speaking generally, solids, liquids, and gases increase in bulk, yet possess the same weight, when subjected to a rise in temperature.

Solids.—In solids, expansion under the influence of heat is a matter of everyday observation; the ends of rails are never placed in contact, (a 20-ft. iron rail expands or contracts ¼ in.); iron bridges are so constructed as to allow of increase in dimensions in summer; wheel tyres are clasped round their centre by the process of "shrinking on." The ratio of the increase of length (when temperature is raised 1°) to the original length, is called the coefficient of linear expansion of a solid. This coefficient naturally varies widely with different metals and solids; for iron it is approximately

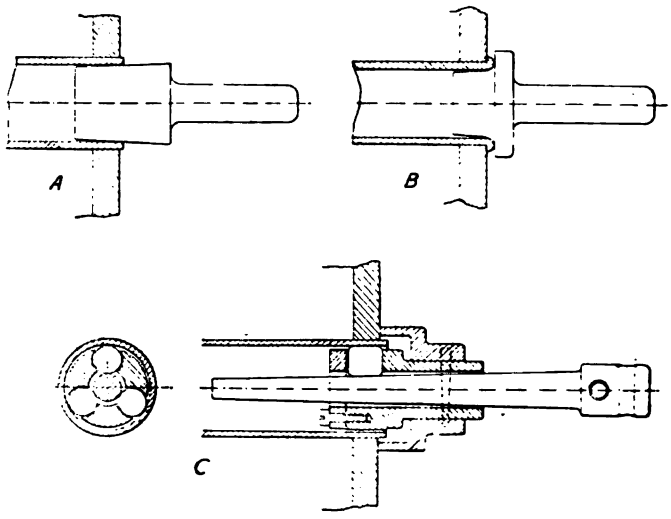


Fig. 211.—Expanding Tools.

·00001; for zinc (which has the greatest coefficient of expansion among metals), ·00290. The difference in degree of expansion is made use of in compensating pendulums and in the balance wheels of chronometers. For square and cubical expansion the coefficients respectively are, the ratio of the original area or volume to the increase in area or volume for 1°. Also the coefficients of square and cubical expansion are twice and three times respectively that of linear expansion.

Liquids.—Liquids expand more than solids and less than gases under the influence of heat. Their increase in volume thus provides a suitable means of measuring temperatures, as in

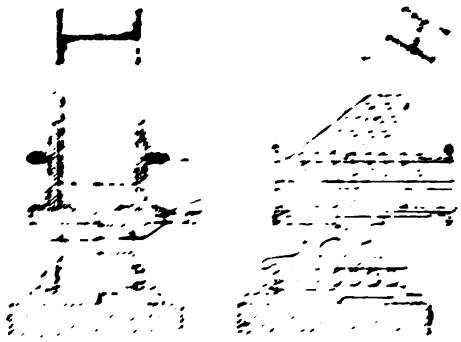


Fig. 212. Expansion Joints of Bridge.

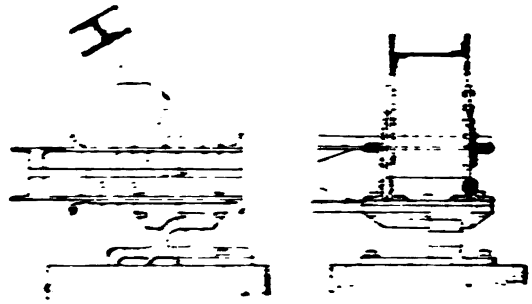


Fig. 213.—Fixed End of Bridge.

have different coefficients of expansion, all dry gases are found to increase in volume to the same extent with equal increments of temperature. For every increase of 1° C. a gas expands $\frac{1}{273}$ of its volume at 0°. This is known as the *Law of Charles*. *See* **Gases**.

Expansion Devices. Metallic structures are primarily sensitive to changes in temperature. This has to be taken account of in some classes of work, though in ordinary mechanisms its effects are negligible. Its effects have to be neutralised in bridges, and boilers; in precision grinding machines, in some machine spindles, and in some measuring instruments.

In some kinds of bridge work, the effects of expansion are neutralised by the natural elasticity of the material, due to the way in which it is disposed. This is the case in arched structures, the effect of expansion being to increase the height of the arch. In some cases where fixed bearings respectively for a bridge over the Nerbudda. At the fixed end, Fig. 213, a broad saddle casting is bolted to a plate riveted to the bottom boom. This saddle fits by its concavity a convexity in a bottom casting bolted to the pier. At the expansion end, Fig. 212, the upper casting is similar to that at the fixed end, but the convex casting rests on live rollers, which rest upon a casting bolted to the pier. The rollers are retained with end cradles. The object of the convex and concave fitting in these examples is to prevent the bridge deflections from throwing the rollers partially out of contact.

The expansions on the Forth Bridge are so great that an allowance of 2 feet was requisite between the cantilevers and central girders. As the effect of the sun shining on one side of the bridge, or of a high wind, is to curve it laterally, this had to be provided against as

well as longitudinal extension. The distance between Inchgarvie and Queensferry is 1,970 feet, and between Inchgarvie and Fife 1,710 feet. The maximum provision made between each of these is 24 inches, and is located at each end of the Inchgarvie cantilever, and so that there should be sufficient play between the middle girders and the cantilevers at the greatest heat of summer. At the mean temperature, which is 70° Fahr., the bottom booms stand away about 1 foot from the ends of the cantilevers. The provision takes the form of a rocking post, pivoted at top and bottom between the top boom of the central girder and the bottom boom of the cantilever, combined with a sliding block, and with expansion joints in the rails. Roller bearings are used in the end piers of the cantilevers, where a movement of 1 foot is provided for.

In steam boilers the effects of expansion have to be guarded against. A locomotive boiler is only fastened rigidly at the fire-box end. Hogging of long horizontal boilers has to be checked by quickening circulation, and by bringing feed water in above the furnaces. Some of the worst ills to which boilers are subject are those due to the working of joints, which produce furrowing and grooving if long continued. Hence the reason why flanges of large radius are preferable to angles, why furnaces and shells should be truly circular instead of having longitudinal lap seams, and why the lengths of furnace flues should be connected with elastic joints.

Expansion is allowed for in grinding machines for shafts and spindles by making the poppet barrel with a spring, so that as the shaft lengthens with the heat of grinding, it is free to expand longitudinally, instead of binding, and curving in the middle, which would instantly produce inaccuracy both cylindrically, and lengthwise. Lathes and grinding machine spindles also have a similar kind of provision, allowing the necessary endlong motion, by avoiding the use of collars or flanges at one end, so that the spindle may slide through its bearings if expansion occurs. The amount is of course slight, but noticeable if not guarded against.

Measuring instruments are especially sensitive to expansion; many of the end measures, and other appliances are fitted with non-conducting handles of vulcanite, &c., so that the heat of the hand does not affect them. Standards of length are only correct at certain temperatures, which must be observed, in order that expansion or contraction shall not affect the measurements taken.

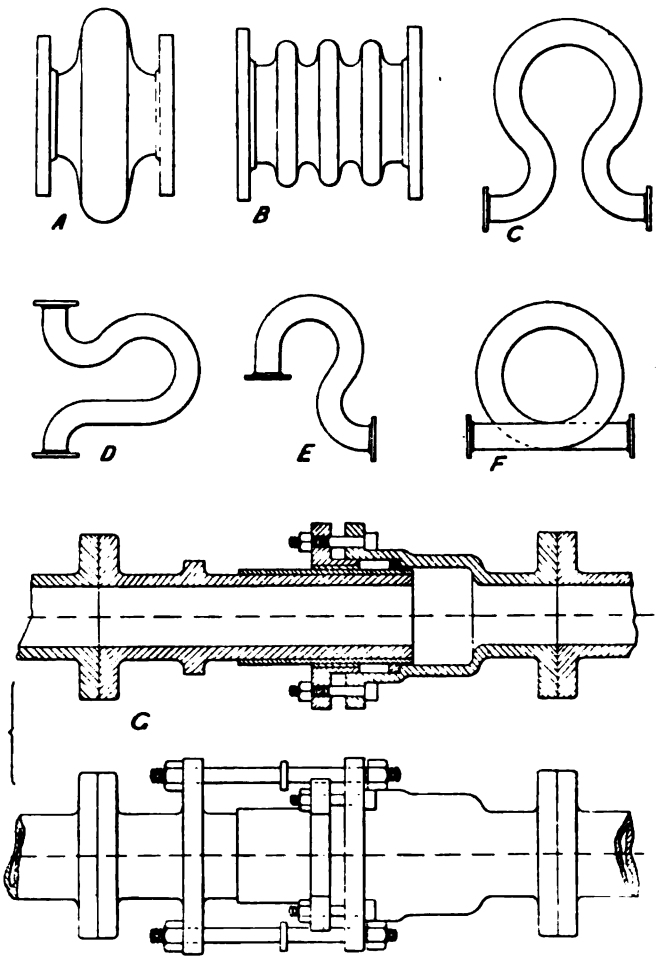


Fig. 214.—Expansion Joints.

Expansion Gear.—*See* **Valve Gears.**

Expansion Joints.—The expansion of steam pipes has to be taken account of, and devices introduced to accommodate the differences in length, otherwise strains and leakages will occur. The expansion of various metals used for piping is as follows:—

Expansion per 10 feet for a rise of 10° Fahr.

Copper.	Steel.	Cast Iron.	Wrought Iron.
·012 in.	·00822 in.	·0077 in.	·0082 in.

Two devices are adopted, that of flexible pipe joints, and sliding joints. Examples of the first-named are shown in Fig. 214, A being the bellows type, allowing of a range of movement between the two flanges, bolted to the piping at either side; screwed unions may alternatively be used. The concertina pattern, B, has three or more rings between the flanges. The loop, C, gives a considerable movement between pipes lying in line, while D is used for those in vertical relations. E connects to vertical and horizontal pipes; and the complete loop, F, is an alternative to C. All these may be made in soft copper, but mild steel is also used for the loops, being more trustworthy at the higher temperatures with superheated steam.

The sliding pipe device, Fig. 214, G, consists of a socketed casting bushed with bronze, and having a stuffing-box in which the other pipe moves, fitting by means of a bush on the body. The long bolts seen in the outside view limit the range of movement, and prevent the joint from being blown apart.

Expansive Working.—*See* **Compound Engine, Compounding.**

Explosives.—For the different explosives, see specific headings, as **Blasting, Cordite, Dynamite, Gun-Cotton, Gunpowder,** &c., &c.

Express Boiler.—A term which has been applied to the water-tube form of boiler in which the tubes are inclined approximately to the vertical direction, as distinguished from those in which they are inclined but slightly from the horizontal. The Thornycroft, and the Yarrow are the best known types of express boilers, used on torpedo boats and destroyers principally; and frequently having tubes of larger size than those employed in the nearly horizontal arrangements.

Extensometer.—An instrument designed to obtain the elastic limit of a specimen bar subjected to tension. See the article **Elastic Limit.** Although for much practical work a pair of dividers may be used, set in elongation points on the specimen bar, this is not sufficiently accurate for scientific purposes, hence the use of the extensometer. There are several of these, by which direct extensions of $\frac{1}{10000}$ of an inch may be measured, and much higher ones indicated. They mostly depend for their accuracy on a fine-pitched screw, and a pointer for multiplying the movement of the screw. The principal forms are those by Professors Unwin, Ewing; Messrs Henning & Marshall, and Riehlé Bros. In some cases a mirror is used, or a microscope.

External Forces.—These, as the term implies, are forces acting on a body from without. Thus, tensile and compressive stresses on ties and struts respectively are external forces, and produce strains.

Externally-Fired Boiler.—One in which the fire, and furnace flues are situated outside the shell. It includes the balloon or haystack boiler, the egg-ended, the elephant, the Rastrick, and the old wagon boiler, all with the exception of a few egg-ended and haystack boilers still in use, being obsolete. The objections to external firing are the small extent of heating surface obtained, the waste of fuel, and the greater liability to explosions.

Extras.—Something charged over list prices for materials in iron and steel. The extras arise in consequence of more work involved in the preparation to dimensions, as in unusual dimensions for which there is little demand; or in cutting to shapes other than rectangular, or are due to stringent tests. The following table for steel will give these differences at a glance.

List of Extras on Boiler Plates, &c.

The Parkgate Iron and Steel Co., Ltd.

For every 3 in. or part over 8 feet wide	2/6	per ton.
For every 5 cwt. or part over 80 cwt.	2/6	,,
Plates under $\frac{3}{8}$ in. to $\frac{5}{16}$ in. thick	2/6	,,
Plates under $\frac{5}{16}$ in. to $\frac{1}{4}$ in. thick	5/	,,
All plates which are not rectangular are to be considered as sketches.		
All sketches and circles extra	25/	,,

In every case where the testing limit is narrowed to 2 tons tensile strain an extra shall be charged of	20/ per ton.
In every case where the range of tensile strain is over 2 and under 3 tons, an extra shall be charged of	10/ ,,
In every case where the range of tensile strain is narrowed to 3 tons, an extra shall be charged of	10/ ,,
Extra for excess weight to be charged on delivered weights.	
End plates of complete specifications to 10 feet wide, free of extra for width.	
Exceeding 10 feet wide, on every 3 in. or part, beginning at 8 feet	2/6 per ton extra.
A guaranteed minimum elongation 25 per cent. in 10 in. ...	20/ ,, ,,
A breaking strain of 2 tons margin	20/ ,, ,,
Welding quality outside complete boiler specification	10/ ,, ,,
Plates over 30 feet long	5/ per ton for every 5 feet or part of 5 feet.
In ordinary complete boiler plate specifications, the proportion of sketches (*i.e.*, plates other than rectangular) should not exceed 15 per cent. Excess over 15 per cent. will be charged	25/ per ton extra.
Ship plates to pass Lloyds' survey, in lots of not less than 60 tons	6d. ,, ,,
Or a minimum charge of	30/
Boiler plates to pass Lloyds', Admiralty, or Board of Trade survey, in lots of not less than 60 tons	1/ per ton extra.
Or a minimum charge of	30/
Sheets $\frac{5}{16}$ in. thick and under.	
If over 9 feet and not over 12 feet long	10/ per ton.
If over 12 feet long	20/ ,,
All gauges, if under 12 in. wide	10/ ,,

Extruded Metal, or "Dixtrudo."—A process invented by Mr Alexander Dick by which heated alloys are squeezed or squirted through dies of many shapes by hydraulic pressure. Sections of extruded metal take the place of those that are otherwise drawn or rolled, and of a larger number that could not be produced by ordinary rolling methods, due to undercutting. The alloy used undergoes so much compression that its strength and ductility are increased, besides which great smoothness of surface is produced.

All the malleable copper alloys are suitable for use in the extrusion process; the aluminium alloys, manganese bronze, brass, yellow metal, and Delta. The increase of strength due to extrusion on Delta is shown as follows:—Delta metal No. I. rolled bar of 45 tons per square inch tensile strength, and an elongation of 20 per cent., had its strength increased by extrusion to 48 tons, and its elongation to 33 per cent. Delta No. IV. rolled bar with a tensile strength of 35·3 tons, and an elongation of 22 per cent., had, after extrusion, a strength of 37 tons, and elongation of 27 per cent.

The steps which led up to the perfecting of this process by Mr Dick are an interesting chapter in the surmounting of great difficulties. We can barely state them here. The temperature necessary to maintain the metal in a sufficiently plastic condition had to be combined with a vessel sufficiently strong to withstand the pressure of many tons per square inch. The difficulty was that, at a temperature of from 800° Fahr., to 900° Fahr., steel retains only about 30 per cent. of its original strength. The first cylinders were made from 3 in. to 6 in. thick, with an annular coke fire. But they cracked at 3 tons, and under, per square inch, due to the unequal expansion and contraction set up. Success came by building up a compound container, with a thin lining wall of steel, reinforced by surrounding steel parts, which are insulated and supported by spaces packed with a dense non-conducting material.

The general design of the machine is that of a horizontal hydraulic ram, the container being the compressing cylinder. It is changed as required for different work. It is mounted on trunnions similarly to a Bessemer converter, and fitted with worm gearing for bringing it into the vertical position, to be charged with metal, and for returning it to the horizontal for the operation of extruding. The die plates are removable for the production of different sections, and are formed with one, or with several openings. At first the application of Mr Dick's method was limited to solid bars and rods. Subsequently tubes of any section were produced.

An interesting fact, and one of value respecting the extruded metal, is that though it cannot be turned to the greatest advantage at ordinary speeds, yet excellent results follow when the speed is increased by three or four times.

Speeds of 1,000 revolutions per minute on 1-in. rods have been found the most practicable.

Eye Bolt.—*See* **Bolt.**

Eyes.—Rings or loops of moderate dimensions on rods, or valve bridles, or tie rods. They are generally forgings in iron or steel, though sometimes made in malleable cast iron.

Small eyes, Fig. 215, A, are formed by punching, with or without subsequent drifting. The objection to the latter is that the fibre is stretched and avoid short fibre, but in steel they may be punched at once. There are different methods of formation in bent eyes. If an eye is bent and welded with a scarf as at B, there is an awkward space left at the joint. A glut *a* is often welded in here. This does not occur in a square eye C. An alternative is to form a ring, and weld the stem on, D, or to fork the end of the stem, and unite it with two scarf welds to the ring, E.

F and G are examples of tie rod eyes that are

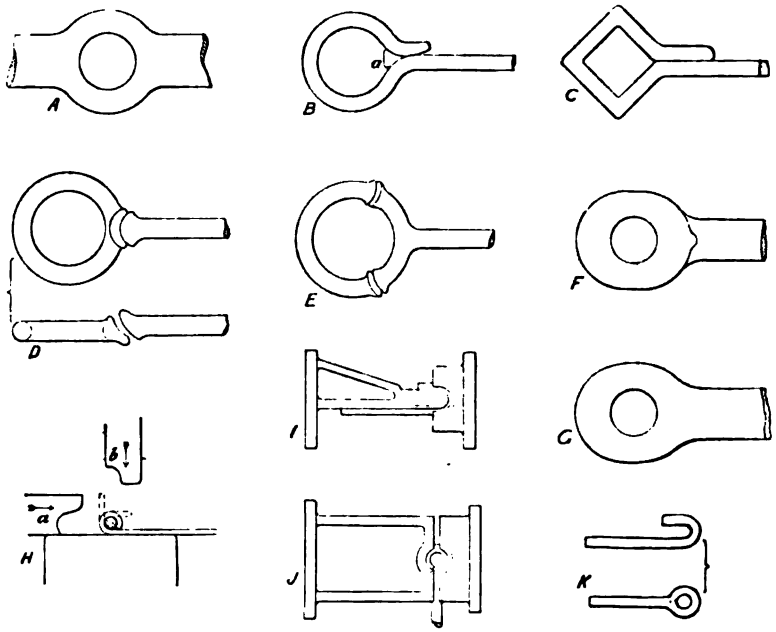


Fig. 215.—Eyes.

opened, so that if much drifting is done, the metal should be closed subsequently by taking a welding heat, and swaging the eye with the drift in place. Or if the work is done in dies, the eye may be coerced in the dies during the time of drifting.

There is a limit to the dimensions of eyes that can be safely made by punching in iron, which does not exist in steel. Large eyes, B - E, must be bent and welded in iron to almost invariably welded to their rods, because of the great length of the latter. These can be punched in iron or in steel. They are commonly finished in dies. H shows an eye being turned in a hydraulic forging press, having two rams, *a* and *b*, moving horizontally and vertically. *a* turns first, and *b* completes the eye. I and J are a pair of dies used on the Bulldozer, I giving the first bending, and J completing the eye round a mandrel. K shows the two stages.

F

Face Lathe.—This resembles in outline the **Break Lathe**, minus a poppet and short bed, the work being supported only by the face plate, for boring, turning, or facing. It is adapted for working on wheels, tyres, flywheels, and other circular objects of no great depth. When provided with a chuck instead of a plain face plate it is sometimes termed a chuck lathe.

Fig. 216, Plate XVI., shows a face lathe with duplex rests, suited for wheel and tyre work. Single, double, and treble gear is fitted. The plate is provided with auxiliary slides, carrying jaws moved in or out by screw, and securely locked by bolts.

In Fig. 217, Plate XVI., a lathe is shown with an auxiliary boring bar, actuated from a poppet, at various speeds, by speed cones. The other end of the bar slides in a bush in the face plate.

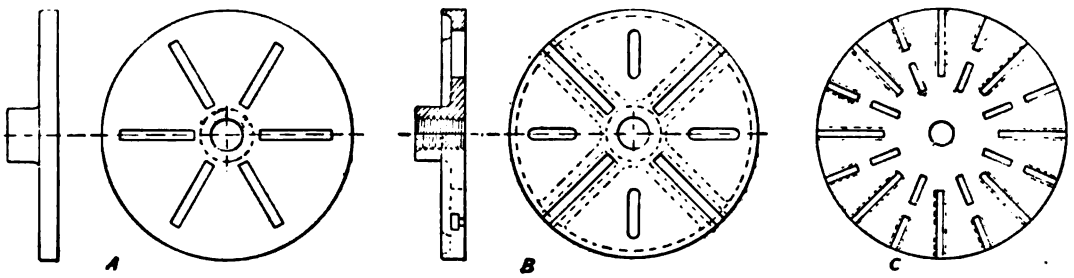


Fig. 218.—Face Plates.

Face Plate.—This is used on wood and metal-turning lathes for the attachment of pieces which cannot be held between centres, or in small chucks. The patternmaker's plate usually consists of a small disc of iron or brass screwed to the lathe mandrel, and having several holes by which a larger wood disc is screwed on, and sometimes also another disc or blocking, to which the work is attached. Frequent facing up may be done on the wood to keep it true, or to recess it to suit a particular shape of job, the wood being readily renewable.

For metal turning the plate is generally as large as the lathe will swing, and the work is held by means of bolts and clamps. A large number of holes or slots must therefore be provided in the plate to accommodate a wide range of shapes and sizes. Plain or tapped holes are used, especially for many small plates, but slots are preferable, because they allow of shifting the bolts about readily to suit circumstances, instead of taking them right out and replacing. A common plate, Fig. 218, A, is shown with six bolt slots. At B a type with tee-slots is shown, possessing the advantage that the bolts can be inserted without having to pass them through from the back. The rim is also stiffened with a rib on the back, which prevents risk of distortion through excessive clamping. Very frequently a combination of through slots and tee-slots is provided in one plate as at B. The larger plates necessarily have a greater number of slots, and these are varied considerably. C illustrates one pattern, with tee-slots reaching to the edge, and plain slots located between. By carrying the tee-slots to the periphery, bolts may be placed right out to the greatest diameter, an advantage not possessed by the plain slots.

The clamping devices used on face plates comprise bolts, straps, or clamping plates, and dogs or poppets. Detachable face-plate jaws are also employed. One form of strap has solid packing under the tail end, another with

a screw which permits of adjustments, and avoids the use of loose packing. When the face of the work must be left free, a poppet must be used, with a screw pressing on the periphery of the job. As this does not afford a very secure hold, modifications are made, with blocks mounted on the screw ends, to give more gripping surface. These are especially popular on the Continent. A more effective device, however, is that of face-plate jaws, resembling those on chucks, but detachable to leave the plate clear when necessary. A common type is bolted to double grooves in large plates, and with a movable jaw actuated by a screw with a squared neck. Four of these fittings are used on the face plate, and are adjusted radially to the approximate diameter required, and the final movement and grip is obtained by setting the jaws. A design modelled on the ordinary chuck jaw is used, permitting of reversal of the jaw by running it out, and turning end for end. The screw engages in a segment nut on the back to allow of this running right off.

The precautions necessary in face-plate work are those arising from risk of distortion, because many light pieces are easily sprung by the clamps, and unless adequate support is given to the work underneath certain portions, inaccurate results follow. Wood or metal blocking is employed for packing up, and, when the weight of the plate allows, the setting should be done horizontally on a bench, for convenience. The testing for concentricity is done by chalk, or an indicator held in the slide rest, the clamps being only tightened up lightly to let the work be adjusted by tapping in the direction required.

The addition of an angle plate converts the face plate into a most useful chuck, and enables work to be held easily which would otherwise involve great trouble in packing up and adjusting. Valves and fittings of various kinds, with faces at right angles, are examples of angle-plate work. In order to bolt the plates to the face plates, the latter are often made with a set of parallel slots, which give a range of movement to and from the lathe centre; the usual radial slots do not lend themselves to this form of adjustment.

Facing Arm.—An attachment to the boring bar, consisting of a form of slide rest, clamped to the bar, and having a tool block fed in or out at right angles to the axis of the bar, by a screw actuated by a star wheel which is struck at each revolution, and partly rotates the feed screw. By this device the flanges of cylinders, pipes, &c., are trued up at the same setting as for boring. The smaller arms have a single slide only, but the larger ones have double arms, in order that two tools may operate simultaneously, one roughing, and one finishing. Angular faces may be done by having the slide set at an angle.

Facing Sand.—A sand mixture used for ramming next the faces of foundry moulds to a thickness of from 1 in. to 3 in. It is composed of mixtures of new and old sand, with coal dust. The particular mixtures of sands depend on the nature of the work, some being free and open, others heavy and clayey, but coal dust is an essential ingredient in all.

Facing Tools.—For truing up the boss faces around holes after drilling or boring, special tools are employed, which ensure the face being square with the bore. In the general style used in drilling and boring machines, the spindle drives a bar in which a flat cutter is wedged. Instead of the wedge, a set screw may pass up through the end of the bar, and lock the cutter. Another pattern is constructed like the counterbore which was shown in Fig. 164, D, p. 158, except that the cutter is relatively larger to suit the boss diameter.

Chucking and turret lathes require facing tools for the bosses of pulleys, gear blanks, &c., and these resemble very much those used in drilling machines. Frequently, however, instead of two plain sides to the cutter, one is serrated or waved, to rough down the boss first, the other and smooth side coming into action later, and finishing. In the facing bars for heavy turret lathes, the holders are of cast iron, and bolted to the turret face.

Factories—Arrangements of.—This article relates to the general lay out of engineers' works, and not to the particular equipments of the different shops, which are considered under the names of those shops.

The arrangements of factories include the older works, and the extension of the same, and the laying out of new works, with all the advantages due to experience in modern conditions.



Fig. 207.—Machine for Producing Expanded Metal.



Fig. 208.—Concrete in Expanded Metal.

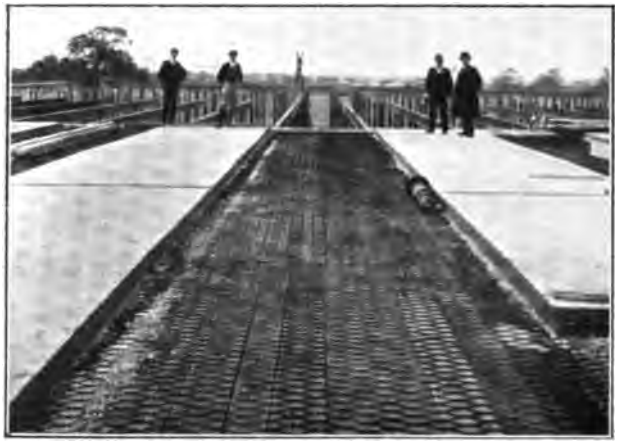


Fig. 209.—Expanded Metal and Concrete Cover for Reservoir.



Fig. 216.—7-Feet Face Lathe with Duplex Rest. (James Spencer & Co.)

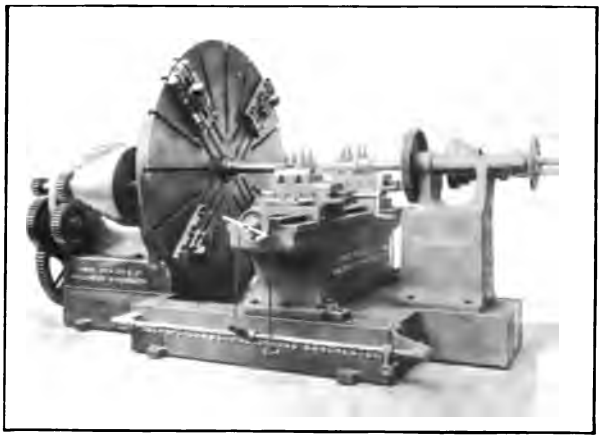


Fig. 217.—9-Ft. Swing Face Lathe with Boring Bar. (James Spencer & Co.)



Fig. 225.—File-Cutting Machine. (Greenwood & Batley, Ltd.)

To face page 224.

The case of the old works offers difficulties by which the new are not hampered.

Old Factories.—The old factories have nearly all grown by accretion, extensions having taken place round the nucleus of an old building or buildings. It has not been possible to plan the extensions from the beginning, but at intervals of a few years, the necessity, unforeseen, has arisen for making them. The result is that such factories have a heterogeneous character, with resulting losses due to want of system and waste of time. Generally the old shops are in thickly populated surroundings, which prevent lateral extension, except at great cost. Frequently, too, they have no connection with railway or stream, so necessitating haulage by trolley of raw materials and finished goods. Sometimes extension takes place by a division of a works into two, separated by a mile or more. Thus a boiler shop may be built away from the old works, or a foundry away from the machine shops.

New Factories.—When these are practicable, the opportunity occurs of making the best possible arrangements of the related shops. Ground is to be sought in the suburbs of cities abutting on rail, or water ways, and of sufficient area to give room for future extension. Often it happens that such a piece of ground is not of the most desirable shape, being irregular in form, so that difficulty is experienced in designing the shops of rectangular shape, and in suitable relations. Herein is the opportunity for the exercise of good judgment. Here, also, differences arise in regard to the requirements of firms handling different classes of work, whether heavy or light, and whether some departments are of small or greater importance. Some firms have no foundry, or boiler, or plating shop. In others, one or all these departments rank of first magnitude. So that in the first place the area required for each separate shop must be estimated, and afterwards how best to arrange them in relation to each other. In these relations the transit of materials and work through the shops, and out again, is of considerable economic importance. The more massive the work, the more essential is it that it shall not have to be carried about from shop to shop by devious ways, or backward and forward, particularly if the means of transit are inadequate. Here the great value of overhead cranes, and of trolley tracks is apparent. If these are absent, or inadequate, there is still greater reason why the work should be kept moving forward in one direction through each shop, and from shop to shop.

Wherever practicable, parallel arrangements of shops should have preference to those standing at diverse angles. The great advantage is that a line of rails can be brought along the ends of the buildings, with turntables. Ground is economised, because all the unoccupied land can be in one or two large areas available for erection and storage. A good alternative method is to have three shops, or groups of shops, enclosing three sides of a rectangular yard available for storage and erection.

There need be no difference in the shape of the cross sections of the buildings for different shops. Thus foundry, machine shop, turnery, smithy, may be all built after similar designs. The differences will consist in their internal arrangements.

A broad distinction between shops is that of *ground floors*, and *storied buildings*. In many cases there can be no choice; since heavy work, boilermaking, foundry work, and smithing, must be done on the ground. But in all work of light and medium sizes the matter is open to choice, and may be determined solely by convenience, such as ground area available, the best way of separating the work, convenience of communication between the different shops, &c. As a general rule the storied shop lends itself best to the light industries, as brass finishing, small motors, pumps, and so on; and generally the best arrangement of storied shops is bounding three, or four sides of an open rectangle. Stairs should be on the outside, and of iron in case of fire, and to economise shop room. Lifts should be installed for the transit of goods and workpeople between floors. A course is often adopted which combines the advantages of both systems. A main bay will be flanked by smaller bays with side galleries. The middle bay is reserved for heavy work, and the side bays and galleries for light machines, and light fittings. An advantage of the shop open to the roof is that ample light is available, whereas with stories, light must come through the side walls.

The saw tooth roof of the spinning and weaving mills has been adopted in many engineering works. It is admirably adapted to parallel arrangements of shops, and direct sunlight is avoided by making all the windows face the north.

Tiles are too heavy for large roofs, for which slates only are suitable. A waterproof felting is often inserted with advantage between the slates and a matchboard lining.

The walls of shops are built on two systems; one with bricks or stone, solidly, and strong enough to sustain the overhead crane tracks and lines of shafting. The other is to build the skeleton of iron or steel columns and girders, and fill in the spaces with corrugated steel, or with a light wall the length of a brick in thickness, or of matchboarding. The column device is cheaper than masonry, and as suitable. The columns afford excellent support to bearing brackets, and pipes for heating. Cast iron or steel-plating are equally suitable for columns. A building constructed thus can be extended uniformly lengthwise by simple repetition of columns, girders, and filling in walls.

When practicable the offices should occupy a central position among the shops, to facilitate visits of the principals and office staff to the works.

Factor of Safety.—A margin allowed beyond either the ultimate strength, or the elastic strength of a structure, which is necessary to ensure safety in working. It is therefore an empirical factor, and is largely an allowance for contingencies, due to hidden defects in material and in construction, which no ordinary testing or inspection can be relied on to reveal. But it is also related to the nature of the load imposed on a structure or machine. Thus the margin for a purely statical load may not be more than from four to six times the elastic limit, while with live loads it may range to twenty. Again in materials subject to decay, such as timber, it may be as high as thirty or forty; or in machines subject to sudden shocks of an incalculable amount, as in cranes, it will be high.

Factors.—In mathematics, a factor is any one of the numbers from the multiplication of which the product results. 12 and 6 are factors of 72; x and y are factors of xy. Some numbers have no factor, *i.e.*, they cannot be divided by anything greater than unity. Such are 5, 11, 23, 29, &c., and these are called prime numbers. Arithmetical and algebraical calculations are greatly facilitated by factorising, and, as shown under **Cancellation**, complex fractions are immediately simplified by striking out the highest common factor.

The factors of algebraical quantities are often evident on inspection. Thus $ax + ay + bx + by = a(x+y) + b(x+y) = (a+b)(x+y)$. To factorise $x^2 + 9x + 20$ it is necessary to find two numbers such that their sum = 9 and their product = 20. These are evidently 4 and 5, and the factors = $(x+4)(x+5)$. Similarly $x^2 - 5x + 6 = (x-2)(x-3)$, the product of the terms -3 and -2 being 6 and their sum -5. Again $x^2 - 2x - 15 = (x+3)(x-5)$ the terms 3 and -5 giving a sum of -2 and a product of -15.

Certain formulæ, however, occur so frequently and are so valuable that they are worth memorising. The three commonest types are:—

$$a^2 + 2ab + b^2 = (a+b)^2$$
$$a^2 - 2ab + b^2 = (a-b)^2$$
$$a^2 - b^2 = (a+b)(a-b)$$

By the substitution of concrete for these abstract quantities these formulæ prove useful in ordinary calculations. Suppose it is required to find the difference between 79^2 and 77^2. To avoid laborious multiplication use the third formula:—

$$79^2 - 77^2 = (79+77)(79-77) = 156 \times 2 = 312.$$

Other useful formulæ are:—

$$a^3 - b^3 = (a-b)(a^2 + ab + b^2)$$
$$a^3 + b^3 = (a+b)(a^2 - ab + b^2)$$
$$a^4 - b^4 = (a^2 + b^2)(a^2 - b^2)$$
$$a^3 + 3a^2b + 3ab^2 + b^3 = (a+b)^3$$
$$a^3 - 3a^2b + 3ab^2 - b^3 = (a-b)^3$$

$a^2 + b^2$, $a^4 + b^4$ cannot be resolved into simpler factors, and no expression of the type $x^n + y^n$ is divisible by $x+y$, or $x-y$ when n is an even whole number. *See* **Greatest Common Measure.**

Fagot.—Denotes the mass of puddled bars built up or piled for re-heating and welding preparatory to rolling into sections. *Fagoted Scrap* or *Hammered Scrap* is a pile built of odds and ends of wrought-iron bar and plate

from the forge, re-heated and welded for use in the best work.

Fahrenheit.—*See* **Thermometer.**

Fair.—Signifies that surfaces are flush, or level.

Fairbairn Crane.—A type of fixed crane introduced by the late Sir William Fairbairn. The jib is composed of a single curved girder which enters the foundation and is extended to carry the bottom pivot pin; this pin rests in a suitable toe stop fixed at the base of the foundation. The pressure at the ground level is taken by a live ring of rollers running between machined paths. The necessary hoisting and slewing gear is arranged upon the body of the jib.

The curved form of the jib gives great clearance for bulky loads, and will also clear over the extensive upper works of a battleship; such cranes are therefore peculiarly suited for dockyard service, and most of the English Government yards are well equipped with this type. The motive power is either hand, steam, electricity, or compressed air. The foundation of a Fairbairn crane is somewhat expensive—not only is a large mass of concrete or masonry required, but the central portion must be hollow and the bottom pivot accessible for examination and lubrication. It is usual to line the foundation pit with cast-iron plates, and to provide a pump to clear it from water.

Fairbairn Jib.—The jib of a Fairbairn crane. It consists of a curved girder of box section, the front or inner curve having a much heavier boom section than the outer one; it tapers toward the head and toward the bottom pivot, the maximum dimensions and areas occurring at the ground line. It is designed as a simple cantilever, and is subject to bending moments as in the case of a ship's davit or a crane post. The earlier Fairbairn cranes had the inner boom section of cellular construction, but this is not strictly necessary so long as the requisite boom area be obtained. A slight modification of the Fairbairn jib consists in making it a straight line from a point above the gearing up to the jib head, and substituting bracing bars in place of the solid side webs; such jibs are lighter and are more convenient for shipment than the curved type.

Falling Weight Test. — *See* **Impact Tests.**

Fall of Bodies.—*See* **Gravity.**

Fall of Potential.—The fall of pressure across the two ends of an electrical circuit caused by the increase of its resistance from the heating effect of the current passing in the conductors.

The drop of potential in any circuit may be measured by a voltmeter first placed across the mains with the circuit open, and then with the circuit closed, when a lower reading will be observed, the difference between the two readings being the drop. If the resistance is known, the drop may be calculated for different currents, when $C \times R =$ drop of potential.

As drop represents power wasted in heating the conductor, and is a continuous loss, it should be kept low by providing conductors of large area, and therefore low resistance, in regard to the proposed current. Thus in designing a cable to transmit 100 ampères at 200 volts to a point 500 feet away, suppose we use a cable of 7/16 S.W.G. R will then for 1,000 feet of cable required for lead and return = ·362 ohm.

·362 ohm × 100 ampères = 36·2 volts drop.

This means that 3·62 Board of Trade units of electricity will be absolutely wasted in heating the cable during every hour that it is in use. Whereas if the proper size of cable, 19/14 S.W.G., were used, then for 1,000 ft.:—

R = ·0855 ohm × 100 ampères = 8·55 volts drop.

Then ·085 unit only per hour is lost. Thus the importance of keeping the cables large enough for their work, to economise power as well as to obviate the dangers of fire from their overheating, may be observed.

False Core.—A cod of sand in a foundry mould, which while fulfilling the function of a core, has not been made separately in a core box. It is rammed up against the pattern, and jointed with parting sand against the body of the mould. It is therefore easily removable, and can be returned into its exact original position as readily as a core can be inserted in a print impression. A false core is necessary when the sand comprising its mould would, if solid with the rest of the mould, be in the way of the delivery of the pattern; or, when it is at least desirable

to be able to remove it temporarily for purposes of mending and cleaning up. The most elaborate examples of false cores occur in statue founding.

False Water.—When a boiler is priming, the water often rises in the gauge glass to a higher level than the solid water in the boiler, hence the term false water.

Fan.—A fan is an instrument which, by causing air to travel rapidly in a circular path, endows it with energy, and the air endeavours to obey that law of motion which says that the unrestrained movement of all bodies is rectilinear. The fan in its simple form consists of an axis carrying a number of flat blades set radially on the spindle to form a spoke wheel without a rim. This wheel revolves in a close fitting case, open at the eye or round the spindle for admission of air, and extended at one point on the circumference to form an outlet tangentially from the casing. Most fans have the blades only on the outer half of the arms, and the blades are closed in by side plates. For low pressures and large volumes, the blades are wide and the velocity low. Such fans are useful for ventilation when much air is to be moved and it is not desired to endow it with much energy, for the energy consumed varies with the square of the velocity. For blowing forges the pressure must be higher, and the fan is run at a high velocity, and made narrow so as to avoid propelling a large weight of air.

Air and other gases exercise a pressure which varies with their velocity. The velocity of a falling body is $V = \sqrt{2gh}$, or $V = \sqrt{64{\cdot}4h}$, where h is the height of fall, and V = velocity in feet per second. Gravity is 32·2. Approximately the formula is used as $V = 8\sqrt{h}$. Taking water as unity, a pressure of 3 in. of water will be secured with a head of 0·11 lb., for 12 in. of water give a pressure of 0·43 lb. This will be 1·76 ounce.

The velocity of flow of water at this pressure of $\frac{1}{4}$ ft. will be $V = 8\sqrt{0{\cdot}25} = 4$ ft. per second. Now air has a density about $\frac{1}{800}$ that of water,

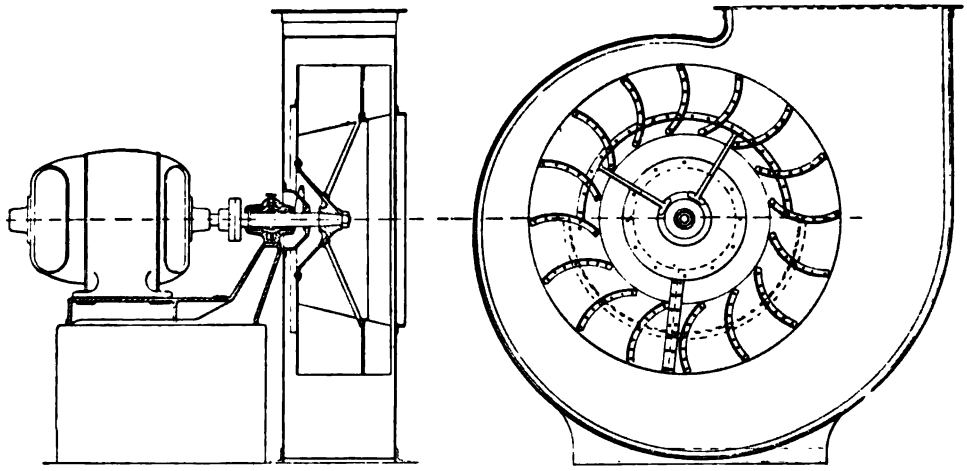


Fig. 219.—Ventilating Fan. (Heenan & Froude, Ltd.)

and a column of air, to exert a pressure equal to 3 in. of water, must have a height of 200 ft. The velocity of flow due to a height of 200 ft. of fall is $V = 8\sqrt{200} = 113$ ft. per second. Thus a fan with a circumference at the tip of the blades of 3 ft. must have a speed of $113 \div 3 =$ 38 per second very nearly, or say 2,280 revolutions per minute, and it will give a water gauge pressure of 3 in.

A convenient formula for the velocity of flow corresponding to any pressure of air in inches h of water gauge is $V = 64\sqrt{h}$. Fans of which the tips of the blades curve slightly forward are said to be more efficient than purely straight blades, because the escaping air is more thor-

oughly impressed with the velocity of the tip. In order to proportion the circumferential discharge area of a fan to the reduced area of inlet at the lesser circumference of the inner ends of the blades, the fan disc is made narrower on the larger circumference. Fans will give an output of about 50 per cent. of the power of the engine driving them.

The construction of a 5 ft. 6 in. ventilating fan is shown in Fig. 219. The drive is by direct-coupled motor. The body of the casing, and the fan wheel are of $\frac{1}{8}$-in. plate, except on the back portion of the wheel, nearest the motor, where $\frac{3}{16}$-in. is used. The vanes are also of

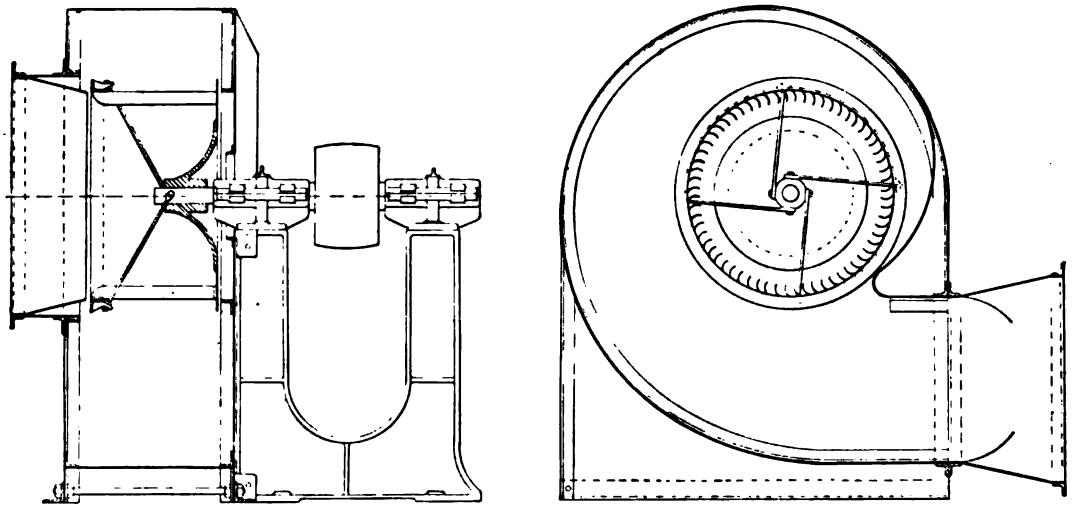


Fig. 220.—"Sirocco" Fan. (Davidson & Co., Ltd.)

$\frac{1}{8}$-in. stuff. The method of building up will be apparent from the drawings.

The "Sirocco" fan, Fig. 220, differs from others in having a large number of blades of shallow radial measurement, and long axial measurement. Their outer edges are curved forward in the direction of rotation, and the air passages between the blades are open at the ends towards the inflowing air. The air inlet and the outlet for discharge are approximately equal in diameter to the fan itself. The example shown is arranged for belt drive. The advantages claimed are that the volume of air discharged is greater, and the velocity higher than in ordinary fans of similar diameter. The velocity of the air exceeds the circumferential speed of the blades by about 80 per cent., so that these fans may be run at much lower speeds for the same effect. There is also no end thrust on the fan shaft.

Farad.—The unit of electrical capacity representing the quantity of electricity in Coulombs at one volt pressure which is required to charge the dielectric of a cable before current can be transmitted along it. The practical unit is Microfarad, equal to one-millionth part of a Farad. Thus with unidirectional current, in a cable having a capacity of a given number of Microfarads, a certain quantity of electricity is absorbed in first charging the dielectric each time the current is switched on, which is discharged when the current is switched off. With alternating current, however, this quantity for charging is absorbed afresh each time the direction of current is changed, so that, with periodicities of 80 to 100 per second, capacity of cables becomes of much more importance in alternating current practice. The rapid reversals of polarity in the current charging the capacities of the dielectric of the cables used produces a heating effect tending to damage their insulation, in addition to the "Resonance" or surgings of current in the circuit. Capacity also interferes with the efficiency of submarine

and underground telegraph and telephone cables, limiting their speed of working.

Farnley Iron.—*See* **Iron.**

Fast Head.—The fixed headstock of a lathe, as distinguished from the loose head, or movable poppet.

Fast Pulley.—Used in conjunction with a loose pulley, so that a belt may be thrown from one to the other, to stop or start a movement. The fast pulley is often made slightly larger in diameter than the loose one, so that the belt runs slack on the latter, thus prolonging its life. The term "tight" is often employed instead of "fast."

Fathom.—Like many of our measures of length, the fathom was originally derived from the human body, and equalled the stretch of both arms. The following table shows its relation to the foot, cable, and knot:—

6 feet	- -	= 1 fathom.
120 fathoms	-	= 1 cable's length.
1,000 fathoms	-	= 1 nautical mile or knot.

Cordage and chains are sold by the fathom.

Fatigue of Materials.—Deterioration in the strength of materials, so that they will fracture under loads much lower than those which they had previously sustained with safety. This is doubtless due to permanent set, and molecular change. Materials subjected to a purely dead or statical load suffer little from fatigue, but those subjected to live loads, and especially those in which the nature of the stress, and the number of its repetitions vary, suffer much from fatigue. This is the case with bridges, shafts, flywheels, reciprocating parts, &c. The experience of all engineers recalls numerous cases of failure due to degeneration of material under stress.

Faucet.—The socket end of a pipe as distinguished from the spigot end. A faucet joint is a socket joint, and a faucet cock or valve is one having sockets instead of flanges.

Faure Secondary Cell.—A secondary cell in which plates or grids carrying a paste made of red lead and sulphuric acid form the + electrodes; the cathodes, or − plates, are grids having their holes filled with spongy lead. Thus two chemically different electrodes, which in a suitable electrolyte have an initial E.M.F., and consequently require a much shorter time for *Formation*, are obtained. *See* **Storage Batteries.**

Feather Edge.—When an edge is chamfered down to nothing or to no thickness the above term is applied to it.

Feather Key.—A key which is sunk into a shaft, and has no endlong motion, unlike the gib key. The top is either tapered or parallel. When tapered it holds a wheel or lever tightly on; when parallel the wheel may slide, while still rotating, this being used for clutches and pinions which have to be thrown in or out of gear. The term *sunk feather* is also applied. When a driving fit is made, the wedging holds the feather, but when used for sliding, the feather must be secured with countersunk screws to prevent loosening. Two feathers are often fitted for heavy work, on opposite sides of the shaft.

Feeder.—A cable carrying current from a generating station to a distant point where a local *distribution board* is fixed.

In electric tramways working, each section of the line is fed from the power station by separate feeder cables, designed to deliver full pressure to the most distant as well as the nearer sections. *See* **Electric Tramways.**

In electric power transmission, feeder cables of small section carry high pressure alternating current to distant sub-stations. At these points the current is passed through static transformers and reduced to the distributing pressure, if required locally as alternating current. If direct current is required at that point the feeders supply the power for the motor generators or rectifiers employed. *See* **Electric Traction.**

Feeding, or Pumping.—Supplying fresh molten metal to a casting during the process of cooling. It is only adopted in heavy castings or heavy portions of castings, but is necessary in these cases, otherwise the shrinkage of the large body of metal would produce an unsightly depression on the surface. The metal is poured in from hand ladles and the mass kept in movement with a $\frac{1}{4}$-in. or $\frac{3}{8}$-in. iron rod until it becomes too pasty to permit of further movement. This rod is termed a *feeding rod*, and the cup-shaped depression into which the metal is poured is a *feeder-head.*

Feed Motions.—The devices employed for feeding work in various classes of machines are very numerous, and are the subject of much controversy at present. The endeavour to increase output has resulted in improved means of feeding, varying the rates of feed and increasing the strength to suit high-speed conditions. This is especially noticeable in lathes and machine tools, the older belt-driven feeds rapidly giving place to the more positive gear-driven devices. The method commonly in use until these gear feeds were adopted was to fit a stepped belt pulley on the main spindle of the machine, and so obtain several differing rates for each spindle speed, which were connected to the tool or work-carrying holders. The limits imposed by this were restricted range of feeds, and insufficient power to stand heavy work. Two methods are now in common use to overcome these disadvantages, one that of driving from the main spindle to a nest of gears, which provide a large range of changes, the other driving direct from the countershaft or a separate motor, rendering feeds totally independent of spindle speeds. In both cases simple means of rapidly changing speeds of feed are introduced, so that the operator can secure the full advantages without difficulty. The appropriate rate for any given piece of work or any particular operation can therefore be given, instead of putting up with something near enough.

One distinctive difference in feed motions is that of intermittent, and continuous movement. The reciprocating machines, planers, shapers, slotters, have the feed imparted after each stroke to a definite amount, ready for another cut; while milling machines, grinders, and usually lathes have a continuous feed, moving all the time, this being rendered necessary by the nature of the conditions.

Drawings of feed devices may be noted in connection with various machines throughout these volumes.

Feed-Rack.—The rack is utilised very extensively for feeding purposes in lathes and machine tools, being either fixed, and used for a pinion to gear into; or movable, as in planing machines, and reciprocated up and down, to impart rotation to a pinion on the end of the feed-screw.

Feed-Screw, Feed-Shaft.—Both of these devices are employed for feeding the slides of lathes and machine tools. The screw is a more direct means, since it may be made to work in a nut in the slide, but it is not so convenient when two or more movements are wanted at right or other angles, such as in a sliding and surfacing lathe, where the saddle has a longitudinal motion, and the rest a cross-feed. The splined feed-rod is then preferable, because it can actuate the gears for racking along the bed, and also those for working the cross-feed screw, each being thrown into gear as required. The splining of the rod permits the gear driven by it to slide as the saddle moves. A device sometimes applied is to spline the lead-screw of the lathe, and so make it serve the purpose of a feed-shaft as well, the driven gear sliding on the outside of the threads.

Feed Water Filter.—This is a type used for removing the grease from boiler feed waters, for surface condensing engines. A cast-iron casing holds the filtering medium—sawdust, cocoa-nut fibre, cloths, &c.—confining it within grids to prevent escape, and the water passes through perforated pipes from an inlet valve, thence through the material, to an outlet valve, the grease being practically all retained by the filtering medium. A by-pass valve is fitted so that the water may, when necessary, be passed direct into the boiler. A pressure gauge is attached to the side and indicates when pressure rises excessively, due to clogging of the material with oil, &c. Frequent cleaning out is essential, and renewal with fresh absorbent.

Feed Water Heater.—A feed water heater is an apparatus for raising the temperature of feed water partially or wholly to that of the water in the boiler. In correct practice the boiler is confined solely to the evaporation of water from and at the temperature which corresponds to the pressure of steam raised by the boiler. Thus, fed with hot water, a boiler is more efficient as an evaporator, it primes less, and it is not exposed to stresses due to changes of temperature as when fed with water of less temperature. As far as possible feed water should be heated by otherwise waste heat of the furnace gases (*see* **Economiser**) or exhaust

steam. Where jet condensing is employed, the feed water is first drawn from the air pump discharge, having been heated to 100° or 110° Fahr. in the condenser.

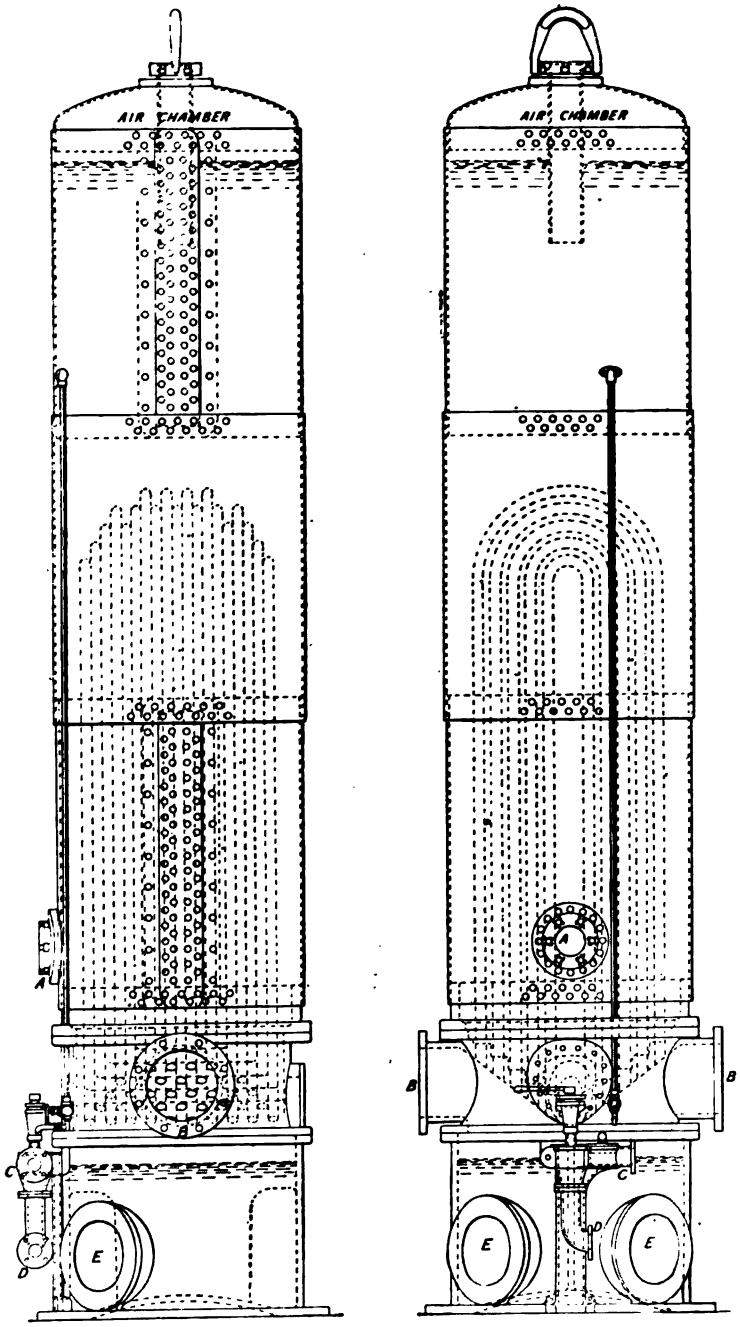


Fig. 221.—Berryman Feed Water Heater. (Joseph Wright & Co.)

Where surface condensation is practised, the discharge from it is used for feed purposes after suitable cleansing from oil. After being cleaned, the water may then pass through an independent section of the surface condenser in order to acquire again the temperature of the exhaust steam before entering the economiser; or perhaps through another surface heater in which it is exposed to the influence of steam at boiler pressure, whereby it may be raised to boiler temperature. In some heaters the water is actually sprayed through the steam space of a chest heater. This is more efficient than surface heating. Mr Weir abstracts steam from the receiver of a compound engine after the steam has done work in the H.P. cylinder, and he is thereby able to heat the feed water to the receiver temperature. In the case of non-condensing engines the exhaust steam is made to pass by way of a surface condenser, and thereby to raise the feed water to 212° Fahr.

The exhaust-steam injector (*see* **Injector**), will heat feed water to 190° Fahr. and deliver it into a boiler against a pressure of 70 lb. or 80 lb. By means of supplementary steam from the boiler, the jet may be further raised in temperature, and forced into boilers at higher pressures.

A very well-known feed heater is Berryman's, Fig. 221. It consists of a double chamber foundation chest, the two chambers being connected by a number of inverted ∩ tubes of various heights and spacing, and the whole are enclosed in a steel-plated

cylinder into which the exhaust steam is passed, the feed water flowing through the ∩ tubes. In Fig. 221 A is the water inlet, B, B the steam inlet or outlet, C is the overflow, D the sludge, E, E, manholes. This, and similar heaters are much used further to heat the water from condensing engines by means of exhaust steam from feed pumps and non-condensing auxiliaries.

In the Cruse system of superheating the temperature of the superheated steam is controlled by means of a water tube inside the superheater tubes. The water which is passed through these control tubes is taken from the economiser or other feed heater, and if necessary partly from the boiler itself, and delivered to the boiler fully heated to the boiler temperature, thus securing the advantages of fully heated feed water, controlled superheat of the steam, and the use of the boiler purely as an evaporator.

Since steam contains ordinarily about 1,100 B.Th.U. of heat above ordinary temperatures, it follows that each 100° of temperature added to feed water above the ordinary temperature will produce an economy of about 9 per cent. of fuel, apart from the reduced wear and tear, and the improved efficiency of the boiler heating surface which also result.

In the illustration of the Weir heater, Fig. 222, A is a float which regulates the steam to the feed pump, B is an air valve to discharge occluded gases, C is the water inlet valve, and D a valve to admit steam to heat the feed.

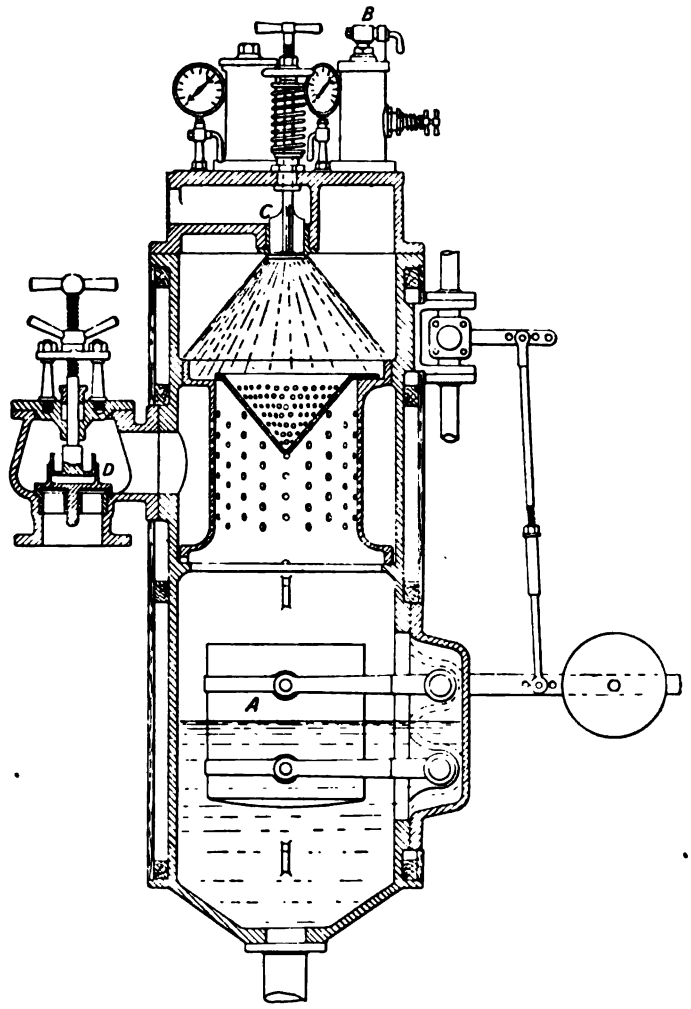


Fig. 222.—Weir Feed Water Heater and Purifier.
(G. & J. Weir, Ltd.)

Feed Waters.—The feed water of boilers is responsible for two of the greatest troubles of the steam user, namely deposit, and incrustation. The difference in the two is indicated by their names, the first being of a more or less loose and friable nature, the second being of a hard and rocky character. But the first, unless promptly removed, usually degenerates into the latter. For incrustation is aggravated, or caused by blowing out boilers without allowing them to cool down first. If blown out while the plates and brick-work are hot, any deposit present is apt to become hardened into incrustation.

Deposit and incrustation are fruitful causes of overheating, leakage, and corrosion, besides offering resistance to the transmission of heat, and so causing waste of fuel. A large proportion of the boiler explosions are due simply

to these causes. The presence of incrustation and deposit also in only moderate amounts vitiates purely theoretical calculations of boiler efficiency.

The salts of lime, of magnesium, and of sodium are the agents of deposit and incrustation.

Rain as it falls is practically free from all foreign matters, having undergone a process of distillation from the sea. But before it has become available for the service of man it has run down the hill sides, percolated through various strata, and become contaminated with salts and solids held in solution, which variously affect its ultimate character. According to the nature and quantity of the foreign matters present the water is broadly denominated "hard," or "soft," the former containing relatively large quantities of the salts of lime, and of magnesia, chiefly in solution, the latter relatively small quantities.

Of these solids, some form scale directly, and some indirectly, while a number are soluble at ordinary boiler temperatures. Only a skilful chemist can ascertain by careful analysis of a water what proportions of salts it contains. But having learned this, it is in many instances practicable to neutralise, or at least to largely minimise the injurious effects of its use.

Deposit and incrustation from fresh water consist chiefly of carbonate of lime, that from sea water, sulphate of lime, and that from the brackish water of estuaries, of nearly equal quantities of each of these salts.

Besides the relative effects which hard and soft water exercise upon boiler plates it is necessary in manufacturing districts to consider the effect which pollution of streams by manufactures has upon feed water drawn from them. Water pumped from mines is frequently also quite unsuitable for use in boilers. In each case the action of such water is corrosive, being due to the presence of acids. In the former they are due to the waste from chemical and galvaniser's works, in the second to the long contact of the water with sulphurous coal.

When it is remembered that ordinary water contains on an average about 30 grains of solid matter per gallon, it is obvious that under unfavourable circumstances, a very few days' accumulations of deposit would suffice to ruin a boiler, and this, in fact, has often happened.

The principal salts which form deposits and incrustation are the carbonate, and sulphate of lime. After these come the sulphate of magnesia, and chloride of sodium. But as the percentage properties vary so much in the water taken from different sources, so will some predominate over others in the importance of their effects.

Carbonate of lime is found in large quantities in nearly all samples of fresh water. It is held in solution by an excess of carbonic acid. In the boiler, this acid is driven off by the heat, and the unsoluble carbonate of lime is precipitated. This is a similar action to that which has been going on in the limestone caves for millenniums past, only that in these the evaporation of the carbonic acid has been effected at the ordinary temperature of the atmosphere, and the deposition of the solid carbonate of lime has therefore been an exceedingly slow affair. In the steam boiler the precipitated carbonate is mostly carried about with the circulating currents, ultimately settling down as a fine deposit in those portions of the boiler where the circulation is least active. Most of this carbonate settles down as fine mud, or slime, and is readily blown out.

Incrustation, or the hard deposit is due chiefly to the presence of sulphate of lime. Its rate of deposition is much slower than that of carbonate, but it is not removable by blowing out. It operates also as a cementing agent, binding together and hardening otherwise muddy deposit. The carbonate and sulphate of lime are direct scale formers, and are the salts most commonly present in solution in fresh water.

Carbonate of lime alone, if judicious treatment is adopted, is not a very troublesome ingredient in feed water. As is well known, it is nearly all deposited from water at, or a little above boiling point, because the boiling expels the carbonic acid, by which the carbonate of lime is held in solution. This solution constitutes what is termed the temporary hardness of water, because this hardness is removed by boiling. In pure water free from

carbonic acid no more than two or three grains can be held in solution, while in water heavily charged with carbonic acid, as much as 85 grains per gallon may be present. When the carbonate of lime is deposited by boiling, the soft deposit may be kept down by frequent blowing off. But the blowing off must not be done while the boiler is hot, else the deposit will become hardened, and form scale upon the plates.

Far more injurious than carbonate of lime is the sulphate of lime. Waters obtained from the New Red Sandstone, which contains large quantities of gypsum are of this character. Calcium sulphate is held in a state of chemical combination with water, forming gypsum, and is dissolved in water without the aid of carbonic acid. At 95° Fahr., the maximum point of solubility, 178 grains per gallon are held in solution. At 212° Fahr. 150 grains are held in solution, so that at that temperature little or no injurious deposition of the salt would take place, no more than could be got rid of by judicious blowing off. The salt would not predominate or become in excess over others, but would be mixed with the rest, and rendered innocuous.

But at higher temperatures the water which is chemically combined with the sulphate of lime is driven off, and the latter being left in an anhydrous condition, is no longer soluble, but is deposited as hard scale. The gypsum begins to lose this water at 260° Fahr., and at 303°, corresponding with a pressure of about 70 lb. per square inch, the sulphate of lime is wholly deposited, and rapidly sets into a hard scale.

The intractability of a sulphate of lime scale is increased by the presence of carbonate of magnesia. This, like carbonate of lime, is held in solution with carbonic acid, producing temporary hardness, which is removed by the expulsion of the carbonic acid on boiling. But further boiling results, as in the case of gypsum, in the formation of magnesium hydrate, which forms a hard scale, and acts as a strong cement to sulphate of lime present.

Silica is a direct scale-forming substance, but though precipitated by boiling water, it is of minor importance by comparison with the salts of lime. Only in rare cases does it appear in considerable quantity, and then chiefly in boilers worked at a low pressure, where the sulphate of lime is not precipitated.

The mode of action of the salts which form scale, or produce corrosion indirectly is not so clearly understood as that of the direct scale formers. Salts ordinarily soluble become deposited when the water is allowed to reach a high degree of concentration. Thus, it is well known that common salt becomes deposited in marine boilers when blowing off is neglected. The chloride of potassium is also a very soluble salt. So too are the nitrates of soda, and potassium; and the chloride, and nitrate of magnesia. But these, though soluble, are nevertheless undesirable, since when decomposed they give off acids which attack and corrode the plates, unless there happens to be sufficient carbonate of lime present, as there often is, to neutralise the acid. But this is not always the case, and where the water is only slightly acid, whether it be so in its natural state, or becomes so by the decomposition of chlorides or nitrates present in it, the result is very fatal to the boiler plates.

Some natural waters are so free from carbonate of lime and magnesia that their softness might seem to render them highly suitable for use in steam boilers. But the absence of alkalinity renders them unsuitable for this purpose, and causes them to be destructive to the boiler plates. But for the fact that the amount of acidity present is usually a variable quantity, it would be comparatively easy to neutralise it by the addition of an alkali. As before remarked, the acidity present in the water is due in some cases to the discharge of acids from galvanising works into streams and canals, and in others to the sulphuric acid present in, and absorbed from an atmosphere charged with the products of combustion of sulphurous coal, and from chemical works. But the percentage proportions of acids will be very variable.

There are salts besides the foregoing which enter to a variable extent into the composition of feed waters. They form a formidable total, in addition to the carbonates and sulphates of lime and magnesia. There are the chlorides, nitrates, and nitrites of calcium, oxide of iron;

gases also, as oxygen, nitrogen, carbonic acid, and sometimes sulphuretted hydrogen.

If the feed waters of boilers contain nitrates and nitrites, they are liable to cause pitting. Pieces of zinc placed in the boiler will counteract their influence. The zinc combines with the oxygen, forming oxide of zinc, and converting the nitrogen into ammonia.

Tannate of soda is also used for the same purpose as the zinc, and so also is a mixture of one part by weight of bisulphate of soda to two parts of soda ash.

If the water in a steam boiler contains any free acid it will cause pitting. This often occurs in water containing free sulphuric acid, as in the case of water pumped from coal mines which contain iron pyrites.

The acidity of water when in a concentrated condition in a steam boiler is easily detected by dropping a little of it on blue litmus paper, when it colours the litmus red. But to detect free acid in this way in the water before it is fed into the boiler, the water must first be concentrated and then tested.

The quantity of solid matter will vary from a mere trace to as much as 280 grains per gallon in some spring water. Hence the chemical reactions that go on in the high temperatures of steam boilers must be of a very complicated character. Many acids are set free by the decomposition of the chlorides of magnesium, carbonate of lime, of the salts of barium and lime, of the salts of sodium and lime, and from the greasy matter introduced into boilers either in feed water heated by exhaust steam, or for the purpose of dissolving deposit. Thus the steam boiler is liable to attack by a host of destructive agencies, some operating with great rapidity, others extending over a long time.

A thin film of incrustation soon forms in all boilers, and is beneficial, because it is a protective covering to the plates. Neither does it interfere sensibly with the transmission of heat. But when persistent deposit occurs, or thick incrustation, or the acids eat into the boiler plates, causing wasting, pitting, and furrowing, then the resources of the steam user are often taxed to the utmost in the effort to ward off these evils.

The methods by which the accumulations of deposit are reduced are, besides the periodical blowing off, and washing out: frequent examination, and scaling when necessary, and the use of solvents to dissolve, and prevent the deposition of the solids. The methods in use embrace :—(1) The treatment of the water with chemicals before it is allowed to enter the boiler; and (2) the treatment of the water with chemicals after it is fed into the boiler.

With regard to the methods of treating the water with chemicals before it is allowed to enter into the boiler, these may take place in softening tanks, or be passed in with the feed, or they may be put into the boiler at intervals of a few days—once, or twice a week.

To prevent or lessen the evils to which steam boilers are subject, common sense would obviously dictate the removal of the deleterious salts from the water before it enters the boiler. But this involves much expense, and the apparatus takes up room.

Dr Clark's process is one that has been employed successfully for a long time to effect the precipitation of carbonate of lime in supply tanks. It consists in the addition of lime water to the feed water contained in tanks. This combining with the carbonic acid in the carbonate of lime, precipitates the lime to the bottom of the tank. *See* **Archbutt-Deeley Process, Clark's Process,** &c.

Various feed water heaters are in use for the double purpose of heating the water, and precipitating the deleterious salts.

The plan of putting chemicals into the boiler at frequent intervals, though often adopted, is not a good one, because of its irregularity of action, and also because the introduction of strong alkalies, especially caustic soda, is apt to corrode the fittings and boiler plates, by setting up a series of galvanic currents between the copper in the brass fittings and the iron of the plates. The chemicals used should preferably be introduced along with the feed, and if a heater is used, then through the heater, the temperature of which will assist in precipitating the salts.

The mode of action of the various boiler compositions used may be very roughly divided under three heads:—(1) Those which act

chemically, precipitating the salts in such a form that they may be removed by the blow-off cock. (2) Those which operate mechanically, preventing the salts from agglomerating into a hard compact mass. (3) Those which increase the solubility of the salts, and so diminish the risk of their deposition.

The principal method is the first, since it includes the various salts of sodium which are used either alone or in admixture with other substances. The commonest of these is the carbonate of soda—in the form of soda ash, and caustic soda. The use of soda is not desirable with waters containing carbonate of lime, because it is liable to become concentrated, and attack the fittings, setting up reactions between the copper and the iron. But with sulphate of lime present in the water in excess of the carbonate, the carbonate of soda left in excess after precipitating the carbonate of lime acts on the sulphate, throwing that down as carbonate thus:—

$$NaCO_3 + CaSO_4 = CaOCO_2 + NaSO_4,$$

and leaving sulphate of soda, a highly soluble salt.

When a water containing sulphate of lime is also acid, then the carbonate of soda is highly useful. Though so valuable an agent, however; to throw a quantity of soda at haphazard into a boiler once or twice a week is a practice to be strongly condemned. It is necessary to have the water analysed by a firm of experts, and to allow them to proportion the quantity of soda to be used.

Tannate of soda is a composition which precipitates the lime as tannate of lime, a loose deposit which is easily blown out.

Tannic acid, and also silicate of soda are substances sometimes used, but are in some respects unreliable.

Sodium fluoride, but for its cost would be very serviceable.

To the second class of compositions, those which prevent the precipitated salts from forming a hard mass, belong potatoes, starch, dextrine, molasses, &c. They mix with the precipitated salts, forming a slimy deposit which is easily blown out.

To the third class, which act by increasing the solubility of the salts that form scale, belongs gelatine. It holds the sulphate of lime in solution at the temperature at which it would naturally be deposited, while permitting of the precipitation of the carbonate of lime along with a portion of gelatine. Since the sulphate of lime is a hardening agent to the carbonate, the advantage of retaining it in solution is great.

It is of little use to employ a boiler composition too sparingly for the purpose it is intended to fulfil. It is injurious to use some compositions in excess. There is no universal medicine suited to all feed waters alike. A composition must be prepared quantitatively for every feed water, and in quantity adapted to the amount of feed required per hour.

Felks.—A term sometimes applied to the segments of built-up flywheels.

Fencing of Machinery.—*See* **Accidents—Prevention of, Guards.**

Fenton's White Metal.—Composed of 8 parts of zinc, 1·66 of tin, 0·44 of copper. It is used for stern bushes, and the bushes of paddle wheels, and resists the wear of sandy water well.

Ferrite.—Iron free from carbon. If a polished specimen is treated with a very dilute solution of nitric acid, or an infusion of liquorice, it is left white and brilliant. Very dilute solutions of nitric acid in alcohol or in water develop the crystalline structure of the ferrite.

Ferro-Alloys.—Alloys of iron with other metallic elements. These have become of great commercial importance dating from the early manufacture of steel by the Bessemer and Open-hearth processes, in which ferro-manganese plays so essential a part. Faraday in 1820 appears to have been the first to recognise the importance of alloying iron with other elements. Ferro-manganese was originally produced in 1865, the alloy being made in crucibles. Ferro-silicon is used to a considerable extent in softening iron for foundry use. Iron is also alloyed with chromium, tungsten, molybdenum, vanadium, nickel, forming ferro-compounds. Many of these are produced by the electric furnace in France, America, and Canada. Ferro-aluminium is used to a considerable extent for the production of sound castings in iron and steel. *See* **Aluminium.**

Ferrules.—Short lengths of tube, of steel, malleable iron, or brass, inserted just within the fire-box ends of the fire-tubes of multitubular boilers of locomotive, and marine (Scotch) type. Their function is to increase the holding power of the tubes. Much controversy has arisen respecting the precise value of these, many believing that they cause the tube ends to burn out more rapidly than plain unferruled tubes.

Many designs of ferrules have been suggested and adopted with a view to lessening the evil of leaky tubes. Much importance is attached

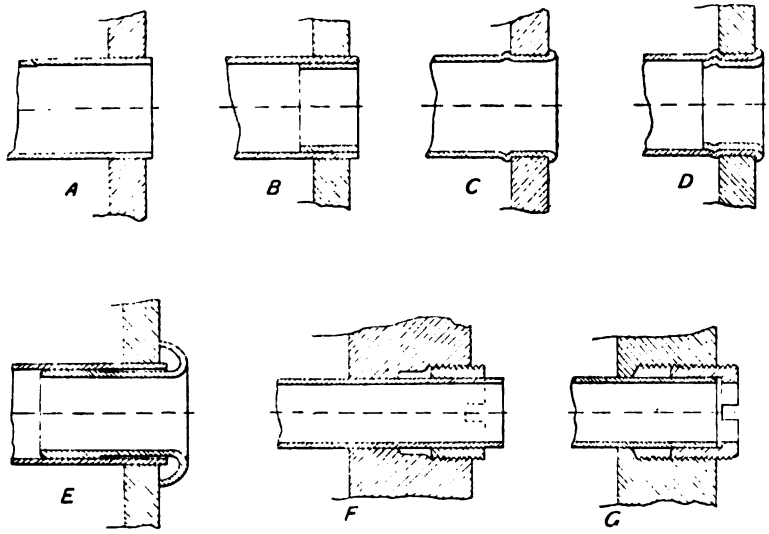


Fig. 223.—Ferrules.

to them by some people, by others they are regarded as makeshifts and temporary expedients to minimise the evils due to defective design.

Ferrules as a rule have not been successful in protecting tube ends from leakage. In the first place they are liable to become overheated through not being in intimate contact with the water in the boiler. They diminish the orifices of the tubes, necessitating an increase of pressure to draw the gases through, and so increasing the tendency to choke the tubes with soot.

Tubes may be expanded simply, or expanded and beaded only, or be ferruled in each case. A few examples are shown in the group of Figs. 223. A is expanded only; B is ferruled and expanded; C is expanded and beaded; D is ferruled, expanded, and beaded. Ferrules and tube ends fit also in tapered holes. Besides these, several special forms of ferrules have been designed by various marine engineers.

Fig. 223, E shows an Admiralty pattern ferrule. The features of this are that there is an air space between the ferrule and the tube, which might be expected to lessen the tendency to overheating in the plate, the ferrule being expanded into the tube within the tube plate, where the heat can be carried away rapidly by the surrounding water. Also that the cap would protect a large area of the tube plate from the destructive action of the fire. The ferrules on trial have been found to protect the tubes from leaking, though they become scaled with oxide. They have been tried both in wrought iron and in cast steel. This ferrule was fitted to H.M.S. *Barracouta* with so great success that it was determined to fit the tubes of the *Thunderer* also with them. This vessel had been lying for some months in 1891 at Gibraltar absolutely unfit for service, solely on account of leaky tubes, leakage occurring even at moderate speeds. She was fitted in 1892 with these ferrules, and the result was eminently satisfactory, 7,000 HP. being easily developed through a four hours' trial with forced draught, being at the rate of about 16 HP. per square foot of grate area, and with entire absence of leakage.

From some experiments conducted in 1877 at the Washington Navy Yard, U.S.A., on the holding power of tubes, the conclusion arrived at was:—that the relative resisting power of tubes fixed by (*a*) expanding, ferruling, and beading; (*b*) expanding, and ferruling; (*c*) expanding only, may be approximately expressed by the figures 5, 2, and 1 respectively. But simple expanding affords more holding power than is ever required in practice, for a

pressure of 800 lb. per square inch would have been required to draw the plate over the tubes.

Condenser ferrules are of a different type, being screwed into the condenser ends with packing, and so rendering the tubes watertight. Two forms are shown in Fig. 223, at F, and G, the latter preventing end-long movement of the tube.

Fettling.—The fettling or cleaning of castings is done in various ways; heavy castings being fettled mostly by hand, light ones by grinding, or in a rumble or rattle barrel. No fettling is or should be done in the moulding shop itself, since it would retard the operations of the men, and fill the sand with dross and scrap iron. All this work should be done in a shed or shop specially set apart for the purpose, and provided with suitable tools and appliances.

In large castings having heavy cores, the first task is the removal of the core bars; or breakage and removal of the core plates, or bricks, as the case may be; and this is often done while the casting is yet red hot, in order to allow of contraction taking place freely without danger of fracture caused by the resistance of the framework of the core. The runner and riser heads are also knocked off while red hot, but not the runners and risers themselves. In this condition, therefore, the castings go into the fettling sheds. The runners and risers are attacked first. One often sees these knocked off with a blow of the hammer, with the result of spoiling or at least disfiguring the casting, the fracture going below the general level of the casting $\frac{1}{4}$ in. or more. The proper way to knock off a runner is to nick it round with a cold chisel, or cold sett. A slight amount of nicking, say $\frac{1}{16}$ in. deep will suffice, so that when the runner is struck with the hammer it will fracture off in the plane of the nick. Then the fractured surface is chipped level with the face of the casting, and filed or ground smooth. If there are small cores in the casting they are now cleared out, grids broken, and wires pulled out, the sand being raked out with an iron bar. Then the fins are knocked off with the hammer, and the joints chipped level, and smoothed with the file, or grinding wheel. If there are scabs present, they will also be chipped off; if blowholes are visible, the attention of the foreman or manager should be called to them to decide whether they are in such a position, or to such an extent, as to condemn the casting. But blowholes as a rule are invisible until machining reveals their presence. But where there are scabs, the presence of blowholes somewhere may be taken for granted. If the blowholes present are not of vital importance, they may be left open, or they may be filled up. Strictly speaking, and in honesty, they ought to be left open, but as a matter of fact they are often filled up. In contract work it is often stipulated that castings shall not be painted until after inspection, but only oiled, and then the holes have to be left as they are. The fettler has now a large number of labour-saving aids. Chief among these are the emery wheels, of bench, and floor types, the pneumatic chisels, the sand blast, the cold saws, and the tumbling barrels.

The fettling shop has been improved greatly in some foundries. Generally any old shed is deemed good enough for this work, and all aids to economy and labour saving have been despised. Not so in a modern foundry. Here labour is saved as much as possible in handling the castings and in cleaning them. Even the dust is not permitted to hang about, but is promptly conveyed away by exhausting fans.

Field Coil.—The coil of wire carrying the current used to excite the magnets of a dynamo or other electrical machine.

Field coils for dynamos and motors are now usually wound on formers or collapsible frames. The coils are then bound up with insulating material, and tape; when the frame is removed, and the centre space being thus of the shape required, the coil is slipped upon the pole piece and held in position by the extended pole tips of the magnets. *See* **Dynamo.**

Field Control.—The control or regulation of the current employed in the excitation of an electro-magnet, by means of a rheostat, or the variation of the pressure from an exciter-dynamo or battery.

Field Magnet.—The electro-magnets used for producing the magnetic field of force in a dynamo-electrical machine. *See* **Dynamo.**

Field, Magnetic.—The magnetic lines of force assumed to be passing between N. and S. poles of a magnet. *See* **Dynamo.**

The field produced within the circle of the closed magnetic circuit formed by an iron ring having a wire coiled spirally around it and carrying a current; or within the coil of a hollow solenoid magnet. *See* **Dynamo** and **Solenoid.**

Field Rheostat.—An adjustable resistance used for varying the strength of magnetic field of a shunt-wound dynamo or motor. By inserting resistance in the field circuit of a dynamo running at constant speed, the voltage at its terminals is reduced. By increasing the resistance in the field circuit of a shunt-wound or compound-wound motor, the speed of its armature revolution is increased.

Field Tubes.—Vertical water tubes, Fig. 224, suspended from the crown of a boiler furnace and hanging down therefrom into the flame. They are double, a tube within a tube, so that the water circulates downwards through the middle tube, and upwards between the two, together with the steam generated. They have been used to a considerable extent, but are troublesome with water that is liable to cause heavy deposit or incrustation, in which case the tubes burn out, and the water leaks, and the tubes have to be replaced. They are used in vertical and in horizontal boilers.

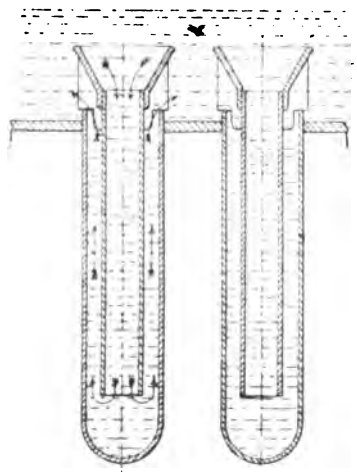


Fig. 224.—Field Tubes.

File Cutting.—This is done both by hand and by machine. The blanks are first forged into shape, and then ground accurately on the faces and edges. In hand cutting, the blank is held down on a block by straps pressed down by the cutter's feet, and the chisel presented at a vertical inclination of from 14° to 4°, depending on the class of file. After striking the first blow, which throws up the metal as a ridge, the chisel is lifted, and replaced on the blank, being slid back until it catches against the ridge cut, and another blow delivered, the process being continued until all the teeth are produced. In double-cut files, the second series of crossing cuts are made more lightly than the first. Rasps are cut with pointed punches, the spacing being determined by the workman, as the burr thrown up cannot be used to pitch the punch as in files.

File-cutting machines have largely taken the place of hand-cutting, although the prejudice against machine-cut files was at one time very strong. In Fig. 225, Plate XVI., a machine for files up to 20 in. long by 1½ in. wide is shown, with the file drawn away from under the chisel. The latter is held in a vertical slide, and is actuated from a cam on the top shaft, the blow being given by a number of flat springs, provided with an arrangement for increasing or decreasing the force of the blow. After the file is clamped down on the bed, and the machine started, the feeding is produced by the rock-shaft seen in front, worked from a crank on the end of the cam-shaft, communicating down to a ratchet feed, which moves a screw, carrying the file forward after each blow. The file-bed is adjustable to any required angle, or the teeth can be given any desired keenness without altering the chisel. The cam-shaft makes 450 revolutions per minute, the machine absorbing 2½ HP. As regards capacity, twenty dozen 14-in. flat files can have their first cut taken in nine hours, the second cut also in nine hours, and cut on the edge in the same period. Used files can be re-cut. All shapes can be produced—flat, square, three-square, either parallel or tapered. Round and half rounds are also cut.

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